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(54) Title: ENHANCED CHEMILUMINESCENCE FROM 1,2-DIOXETANES THROUGH ENERGY TRANSFER TO TETHERED FLUORESCERS

(57) Abstract

Triggerable dioxetanes with a fluorescent molecule containing group bonded or tethered in the dioxetane so as to produce fluorescence from the group are described. The compounds are useful in immunoassays and in probes using enzymes or other chemicals for triggering the dioxetanes to produce light from the fluorescent molecule in the group as a signal.

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ENHANCED CHEMILUMINESCENCE FROM 1,2-DIOXETANES  
THROUGH ENERGY TRANSFER TO TETHERED FLUORESCERS

Cross-Reference to Related Application

This application is a continuation-in-part of U.S. application Serial No. 887,139, filed July 17, 1986.

BACKGROUND OF THE INVENTION

5 (1) Statement of the Invention

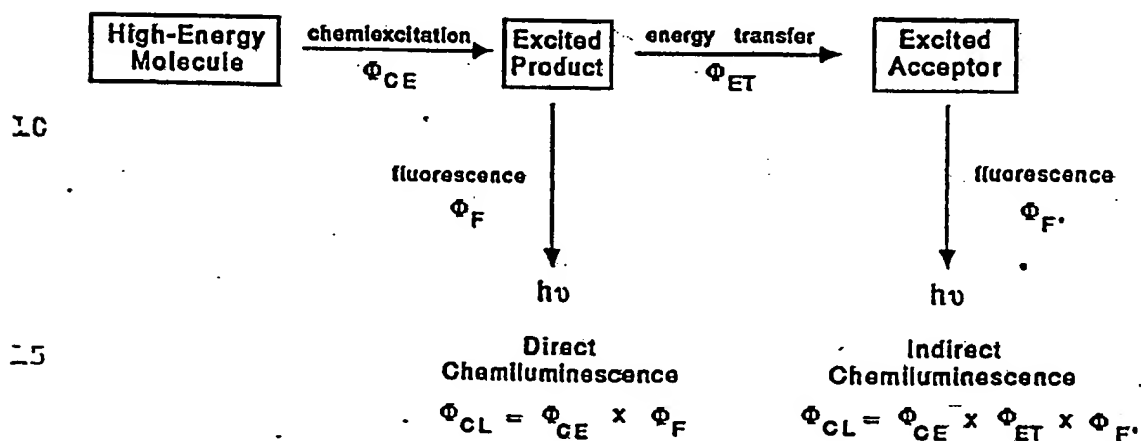
The present invention relates to thermally stable dioxetanes which can be triggered by chemical reagents or enzymes to generate chemiluminescence in organic solvents or in aqueous solution. A method for  
10 significantly enhancing the chemiluminescence efficiency has been discovered which involves intramolecular energy transfer to a fluorescent group which is bonded or "tethered" to the dioxetane molecule. These compounds can be used in various chemiluminescent assays including  
15 enzyme-linked immunoassays and enzyme-linked DNA probes as well as direct, chemically triggerable labels for biomolecules.

(2) PRIOR ART

1. Mechanisms of Luminescence. Exothermic  
20 chemical reactions release energy during the course of the reaction. In virtually all cases, this energy is in the form of vibrational excitation or heat. However, a few chemical processes generate light or chemiluminescence instead of heat. The mechanism for light production  
25 involves thermal or catalyzed decomposition of a high energy material (frequently an organic peroxide such as a 1,2-dioxetane) to produce the reaction product in a triplet or singlet electronic excited states. Fluorescence of the singlet species results in what has been termed direct  
30 chemiluminescence. The chemiluminescence quantum yield is the product of the quantum yields for singlet chemiexcitation and fluorescence. These quantities are often expressed as efficiencies where efficient (%) =  $\Phi \times$

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100. Energy transfer from the triplet or singlet product to a fluorescent acceptor can be utilized to give indirect chemiluminescence. The quantum yield for indirect chemiluminescence is the product of the quantum yields for singlet or triplet chemiexcitation, energy transfer, and fluorescence of the energy acceptor.

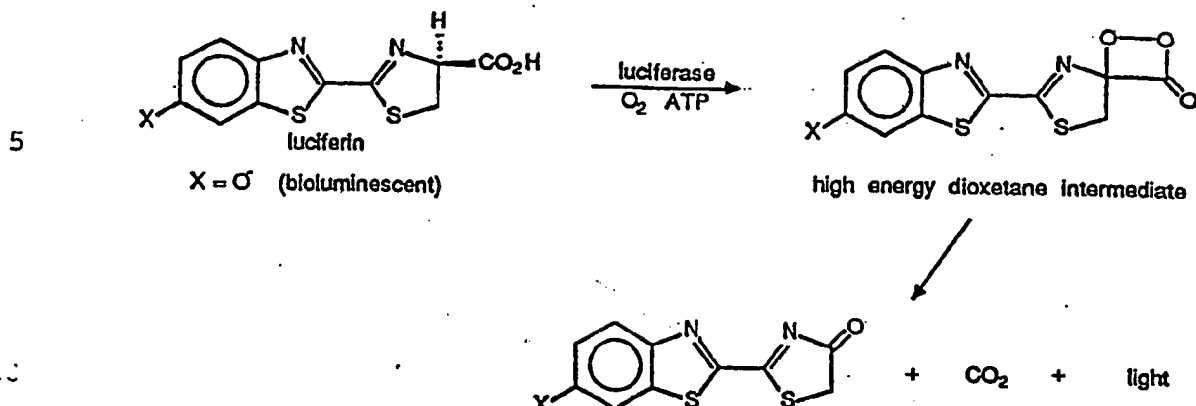


## 2. Dioxetane Intermediates in Bioluminescence.

In 1968 McCapra proposed that 1,2-dioxetanes might be the key high-energy intermediates in various bioluminescent reactions including the firefly system. (F. McCapra, Chem. Commun., 155 (1968)). Although this species is apparently quite unstable and has not been isolated or observed spectroscopically, unambiguous evidence for its intermediacy in the reaction has been provided by oxygen-18 labeling experiments. (O. Shimomura and F. H. Johnson,

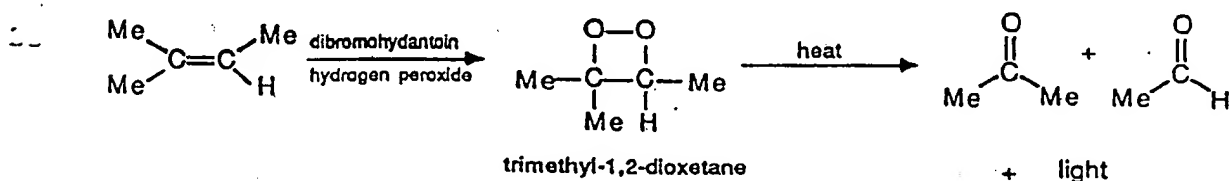
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Photochem. Photobiol., 30, 89 (1979)).



### 3. First Synthesis of Authentic 1,2-Dioxetanes.

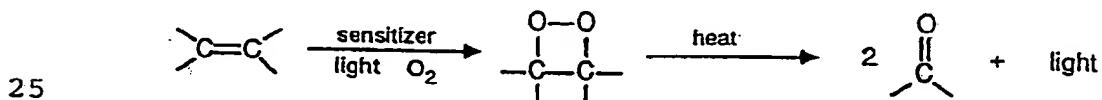
In 1969 Kopecky and Mumford reported the first synthesis of a dioxetane (3,3,4-trimethyl-1,2-dioxetane) by the  
 15 base-catalyzed cyclization of a beta-bromohydroperoxide.  
 (K. R. Kopecky and C. Mumford, Can. J. Chem., 47, 709 (1969)). As predicted by McCapra, this dioxetane did, in fact, produce chemiluminescence upon heating to 50°C with decomposition to acetone and acetaldehyde. However, this  
 20 peroxide is relatively unstable and cannot be stored at room temperature (25°C) without rapid decomposition. In addition, the chemiluminescence efficiency is very low (less than 0.1%).



Bartlett and Schaap and Mazur and Foote  
 30 independently developed an alternative and more convenient synthetic route to 1,2-dioxetanes. Photooxygenation of properly-substituted alkenes in the presence of molecular oxygen and a photosensitizing dye produces dioxetanes in high yields. (P. D. Bartlett and A. P. Schaap, J. Amer. Chem. Soc., 92, 3223 (1970) and S. Mazur and C. S. Foote,  
 35 J. Amer. Chem. Soc., 92, 3225 (1970)). The mechanism of this reaction involves the photochemical generation of a

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metastable species known as singlet oxygen which undergoes 2 + 2 cycloaddition with the alkene to yield the dioxetane. Research has shown that a variety of dioxetanes can be prepared using this reaction (A. P. Schaap, P. A. Burns, and K. A. Zaklika, J. Amer. Chem. Soc., 99, 1270 (1977); K. A. Zaklika, P. A. Burns, and A. P. Schaap, J. Amer. Chem. Soc., 100, 318 (1978); K. A. Zaklika, A. L. Thayer, and A. P. Schaap, J. Amer. Chem. Soc., 100, 4916 (1978); K. A. Zaklika, T. Kissel, A. L. Thayer, P. A. Burns, and A. P. Schaap, Photochem. Photobiol., 30, 35 (1979); and A. P. Schaap, A. L. Thayer, and K. Kees, Organic Photochemical Synthesis, II, 49 (1976)). During the course of this research, a polymer-bound sensitizer for photooxygenations was developed (A. P. Schaap, A. L. Thayer, E. C. Blossey, and D. C. Neckers, J. Amer. Chem. Soc., 97, 3741 (1975); and A. P. Schaap, A. L. Thayer, K. A. Zaklika, and P. C. Valenti, J. Amer. Chem. Soc., 101, 4016 (1979)). This new type of sensitizer has been patented and sold under the tradename SENSITOX<sup>™</sup> (U.S. Patent No. 4,315,998 (2/16/82); Canadian Patent No. 1,044,639 (12/19/79)). Over fifty references have appeared in the literature reporting the use of this product.

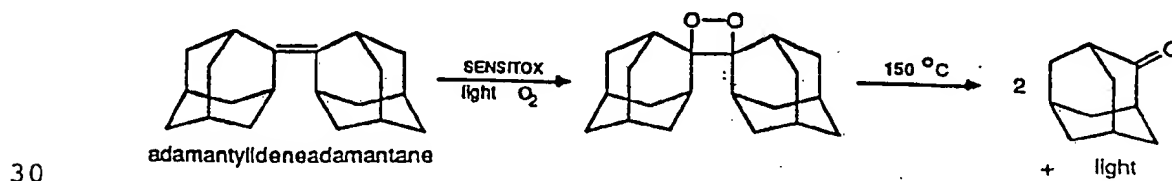


4. Preparation of Stable Dioxetanes Derived from Sterically Hindered Alkenes. Wynberg discovered that photooxygenation of sterically hindered alkenes such as adamantylideneadamantane affords a very stable dioxetane (J. H. Wieringa, J. Strating, H. Wynberg, and W. Adam, Tetrahedron Lett., 169 (1972)). A collaborative study by Turro and Schaap showed that this dioxetane exhibits an activation energy for decomposition of 37 kcal/mol and a half-life at room temperature (25°C) of over 20 years (N. J. Turro, G. Schuster, H. C. Steinmetzer, G. R. Faler, and A. P. Schaap, J. Amer. Chem. Soc., 97, 7110 (1975)). In

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fact, this is the most stable dioxetane yet reported in the literature. Adam and Wynberg have recently suggested that functionalized adamantylideneadamantane 1,2-dioxetanes may be useful for biomedical applications (W. Adam, C.

- 5 Babatsikos, and G. Cilento, Z. Naturforsch., 39b, 679 (1984); H. Wynberg, E. W. Meijer, and J. C. Hummelen, In Bioluminescence and Chemiluminescence, M. A. DeLuca and W. D. McElroy (Eds.) Academic Press, New York, p. 687, 1981; and J. C. Hummelen, T. M. Luider, and H. Wynberg, Methods  
 10 in Enzymology, 133B, 531 (1986)). However, use of this extraordinarily stable peroxide for chemiluminescent labels requires detection temperatures of 150 to 250°C. Clearly, these conditions are unsuitable for the evaluation of biological analytes in aqueous media. McCapra, Adam, and  
 15 Foote have shown that incorporation of a spirofused cyclic or polycyclic alkyl group with a dioxetane can help to stabilize dioxetanes that are relatively unstable in the absence of this sterically bulky group (F. McCapra, I. Beheshti, A. Burford, R. A. Hann, and K. A. Zaklika, J. Chem. Soc., Chem. Commun., 944 (1977); W. Adam, L. A. A. Encarnacion, and K. Zinner, Chem. Ber., 116, 839 (1983); G. G. Geller, C. S. Foote, and D. B. Pechman, Tetrahedron Lett., 673 (1983); P. Lechtken, Chem. Ber., 109, 2862 (1976); and P. D. Bartett and M. S. Ho, J. Amer. Chem. Soc., 96, 627 (1974))  
 25 Soc., 96, 627 (1974))



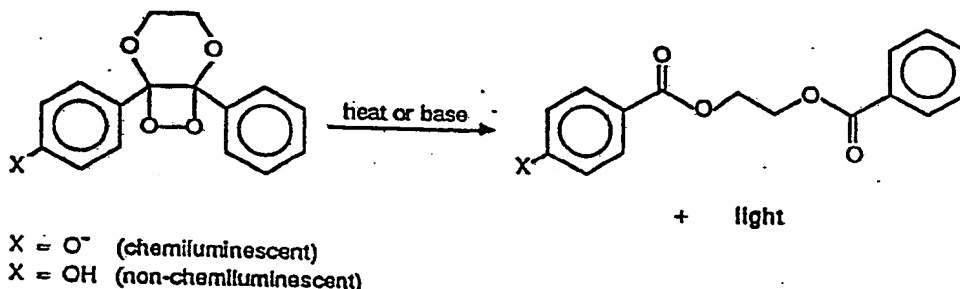
### 5. Effects of Substituents on Dioxetane

Chemiluminescence. The stability and the chemiluminescence efficiency of dioxetanes can be altered by the attachment of specific substituents to the peroxide ring (K. A.

- 35 Zaklika, T. Kissel, A. L. Thayer, P. A. Burns, and A. P. Schaap, Photochem. Photobiol., 30, 35 (1979); A. P. Schaap and S. Gagnon, J. Amer. Chem. Soc., 104, 3504 (1982); A. P.

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Schaap, S. Gagnon, and K. A. Zaklika, Tetrahedron Lett., 2943 (1982); and R. S. Handley, A. J. Stern, and A. P. Schaap, Tetrahedron Lett., 3183 (1985)). The results with the bicyclic system shown below illustrate the profound effect of various functional groups on the properties of dioxetanes. The hydroxy-substituted dioxetane ( $X=OH$ ) derived from the 2,3-diaryl-1,4-dioxene exhibits a half-life for decomposition at room temperature ( $25^{\circ}C$ ) of 57 hours and produces very low levels of luminescence upon heating at elevated temperatures. In contrast, however, reaction of this dioxetane with a base at  $-30^{\circ}C$  affords a flash of blue light visible in a darkened room. Kinetic studies have shown that the deprotonated dioxetane ( $X=O^{-}$ ) decomposes  $5.7 \times 10^6$  times faster than the protonated form ( $X=OH$ ) at  $25^{\circ}C$ .



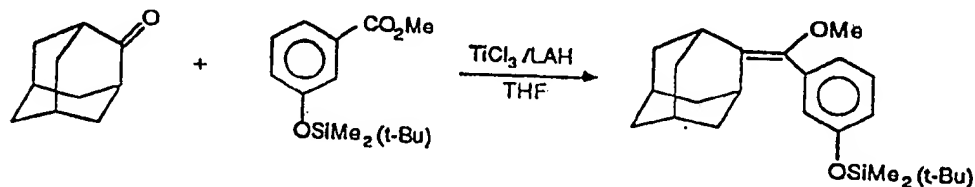
The differences in the properties of these two dioxetanes arise because of two competing mechanisms for decomposition ((K. A. Zaklika, T. Kisse, A. L. Thayer, P. A. Burns, and A. P. Schaap, Photochem. Photobiol., 30, 35 (1979); A. P. Schaap and S. Gagnon, J. Amer. Chem. Soc., 104, 3504 (1982); A. P. Schaap, S. Gagnon, and K. A. Zaklika, Tetrahedron Lett., 2943 (1982); and R. S. Handley, A. J. Stern, and A. P. Schaap, Tetrahedron Lett., 3183 (1985)). Most dioxetanes cleave by a process that involves homolysis of the O-O bond and formation of a biradical. An alternative mechanism is available to dioxetanes bearing substituents such as  $O^{-}$  with low oxidation potentials. The cleavage is initiated by intramolecular electron transfer

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from the substituent to the antibonding orbital of the peroxide bond.

6. Chemical Triggering of Stabilized 1,2-Dioxetanes. We have recently discovered that thermally stable dioxetanes can be triggered by chemical and enzymatic processes to generate chemiluminescence on demand (A. P. Schaap, patent application Serial No. 887,139, filed July 15, 1986; A. P. Schaap, R. S. Handley, and B. P. Giri, Tetrahedron Lett., 935 (1987); A. P. Schaap, T. S. Chen, R. S. Handley, R. DeSilva, and B. P. Giri, Tetrahedron Lett., 1155 (1987); and A. P. Schaap, M. D. Sandison, and R. S. Handley, Tetrahedron Lett., 1159 (1987)). To do this, we have developed new synthetic procedures to produce dioxetanes with several key features: (1) the stabilizing influence of spiro-fused adamantyl groups has been utilized to provide dioxetanes that have "shelf lives" of years at ambient temperature and (2) new methods for triggering the chemiluminescent decomposition of the stabilized dioxetanes have been provided.

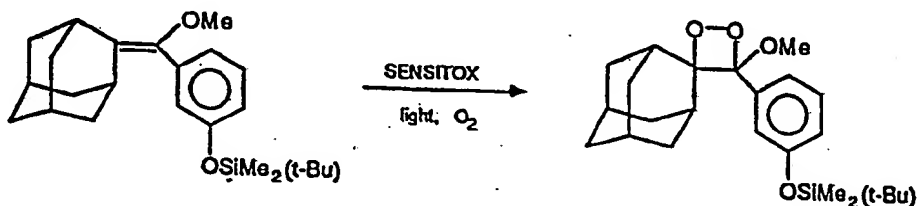
The required alkenes have been prepared by reaction of 2-adamantanone with aromatic esters or ketones using titanium trichloride/LAH in THF (A. P. Schaap, patent application Serial No. 887,139). This is the first report of the intermolecular condensation of ketones and esters to form vinyl ethers using the McMurry procedure. Although McMurry had earlier investigated the intramolecular reaction of ketone and ester functional groups, cyclic ketones and not vinyl ethers were prepared by this method (J. E. McMurry and D. D. Miller, J. Amer. Chem. Soc., 105, 1660 (1983)).



Photooxygenation of these vinyl ethers affords dioxetanes that are easily handled compounds with the

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desired thermal stability. For example, the dioxetane shown below exhibits an activation energy of 28.4 kcal/mol and a half-life at 25°C of 3.8 years. Samples of this dioxetane in o-xylene have remained on the laboratory bench for several months with no detectable decomposition.

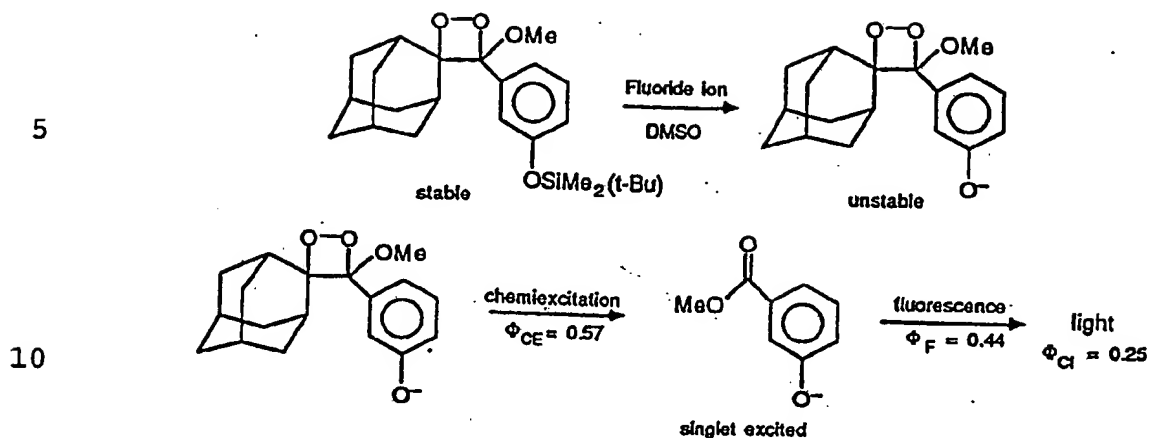


However, the chemiluminescent decomposition of this dioxetane can be conveniently triggered at room temperature by removal of the silyl-protecting with fluoride ion to generate the unstable, aryloxy form which cleaves to yield intense blue light. The half-life of the aryloxy-substituted dioxetane is 5 seconds at 25°C. The spectrum of the chemiluminescence in DMSO exhibited a maximum at 470 nm which is identical to the fluorescence of the anion of the ester cleavage product (methyl 3-hydroxybenzoate) and the fluorescence of the spent dioxetane solution under these conditions. No chemiluminescence derived from adamantanone fluorescence appears to be produced. Chemiluminescence quantum yields for the fluoride-triggered decomposition measured relative to the luminol standard was determined to be 0.25 (or a chemiluminescence efficiency of 25%). Correction for the fluorescence quantum yield of the ester under these conditions ( $\Phi_F = 0.44$ ) gave an efficiency for the formation of the singlet excited ester of 57%, the highest singlet chemiexcitation efficiency yet reported for a dioxetane

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prepared in the laboratory.

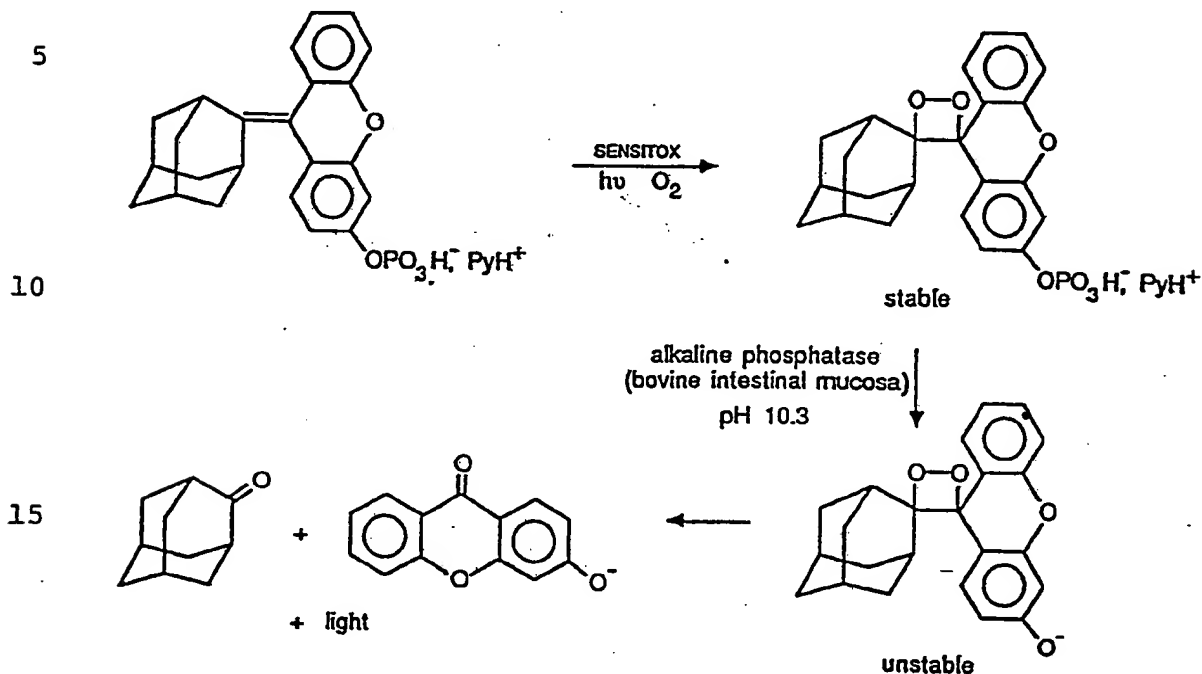


### 7. Enzymatic Triggering of 1,2-Dioxetanes.

Biological assays such as immunoassays and DNA probes involving enzymes utilize a wide variety of substrates which either form a color (chromogenic) or become fluorescent (fluorogenic) upon reaction with the enzyme. As part of our investigation of triggering methods, we developed the first dioxetanes which can function as chemiluminescent enzyme substrates (A. P. Schaap, patent application Serial No. 887,139; A. P. Schaap, R. S. Handley, and B. P. Giri, Tetrahedron Lett., 935 (1987); A. P. Schaap, T. S. Chen, R. S. Handley, R. DeSilva, and B. P. Giri, Tetrahedron Lett., 1155 (1987); and A. P. Schaap, M. D. Sandison, and R. S. Handley, Tetrahedron Lett., 1159 (1987)). Use of these peroxides in biological systems requires dioxetanes which are thermally stable at the temperature of the enzymatic reaction and do not undergo rapid spontaneous decomposition in the aqueous buffers. The spiro-fused adamantyl dioxetanes described in the previous section meet these requirements. We have, therefore, prepared dioxetanes bearing functional groups which can be enzymatically modified to generate the aryloxy form. Decomposition of this unstable intermediate provides the luminescence. Dioxetanes have been synthesized which can be triggered by various enzymes including aryl esterase, acetylcholinesterase, and alkaline

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phosphatase. The phosphatase example is particularly significant because this enzyme is used extensively in enzyme-linked immunoassays.



For example, enzymatic triggering by alkaline phosphatase was observed with the phosphate-substituted dioxetane derived from 3-hydroxy-9H-xanthene-9-one and 2-adamantanone. The dioxetane is thermally stable with an activation energy of 30.7 kcal/mol and a half-life at 25°C of 12 years. The dioxetane is not only stable in organic solvents but also shows very slow spontaneous decomposition in aqueous buffers.

Triggering experiments were conducted using alkaline phosphatase from bovine intestinal mucosa [suspension of 5.3 mg of protein (1100 units/mg protein) per mL in 3.2 M (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>] and the phosphate-protected dioxetane at pH 10.3 in 0.75 M 2-amino-2-methyl-1-propanol buffer. A 50 μL aliquot (0.013 μmol) of a phosphate-dioxetane stock solution was added to 3 mL of the buffer at 37°C to give a final dioxetane concentration of 4.2 x 10<sup>-6</sup> M. Injection of 1 μL (final concentration of protein = 1.8 μg/mL) of alkaline phosphatase to the solution resulted in burst of chemiluminescence that

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decayed over a period of 3 minutes. Over this period of time, the background luminescence from slow non-enzymatic hydrolysis of the dioxetane in the buffer was only 0.2% of that produced by the enzymatic process. The total light emission was found to be linearly dependent on the dioxetane concentration. The rate of decay of the emission is a function of enzyme concentration while the total light emission is independent of the enzyme concentration. The chemiluminescence spectrum for the phosphatase-catalyzed decomposition was obtained at room temperature in the buffer solution. A comparison of this chemiluminescence spectrum with the fluorescence spectrum of the spent reaction mixture and the fluorescence spectrum of the hydroxyxanthanone cleavage product in the buffer indicates that the emission is initiated by the enzymatic cleavage of the phosphate group in dioxetane to yield the unstable aryloxide dioxetane which generates the singlet excited anion of hydroxyxanthanone.

#### Literature Examples

(a) Chemical Triggering of Dioxetanes: The first example in the literature is described above (A. P. Schaap and S. Gagnon, J. Amer. Chem. Soc., 104, 3504 (1982)). However, the hydroxy-substituted dioxetane and any other examples of the dioxetanes derived from the diaryl-1,4-dioxenes are far too unstable to be of use in any application. They have half-lives at 25°C of only a few hours. Neither the dioxetane nor the precursor alkene would survive the conditions necessary to prepare derivatives. Further, these non-stabilized dioxetanes are destroyed by small quantities of amines (T. Wilson, Int. Rev. Sci.: Chem., Ser. Two, 9, 265 (1976)) and metal ions (T. Wilson, M. E. Landis, A. L. Baumstark, and P. D. Bartlett, J. Amer. Chem. Soc., 95, 4765 (1973); P. D. Bartlett, A. L. Baumstark, and M. E. Landis, J. Amer. Chem. Soc., 96, 5557 (1974) and could not be used in the aqueous buffers required for enzymatic triggering.

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The only examples of the chemical triggering of stabilized dioxetanes are reported in the prior patent application (A. P. Schaap, patent application Serial No. 887,139) and a paper (A. P. Schaap, T. S. Chen, R. S. Handley, R. DeSilva, and B. P. Giri, Tetrahedron Lett., 1155 (1987)). These dioxetanes exhibit thermal half-lives of years but can be triggered to produce efficient chemiluminescence on demand.

(b) Enzymatic triggering of Dioxetanes.

Examples of enzymatic triggering of dioxetanes are described in the prior patent applications (A. P. Schaap, patent application Serial No. 887,139) and papers (A. P. Schaap, R. S. Handley, and B. P. Giri, Tetrahedron Lett., 935 (1987) and A. P. Schaap, M. D. Sandison, and R. S. Handley, Tetrahedron Lett., 1159 (1987)).

(c) Energy-Transfer Chemiluminescence Involving Dioxetanes in Homogeneous Solution. The first example of energy-transfer chemiluminescence involving dioxetanes was described by Wilson and Schaap (T. Wilson and A. P. Schaap, J. Amer. Chem. Soc., 93, 4126 (1971)). Thermal decomposition of a very unstable dioxetane (cis-diethoxydioxetane) gave both singlet and triplet excited ethyl formate. Addition of 9,10-diphenylanthracene and 9,10-dibromoanthracene resulted in enhanced chemiluminescence through singlet-singlet and triplet-singlet energy-transfer processes, respectively. These techniques have subsequently been used by many other investigators to determine yields of chemiexcited products generated by the thermolysis of various dioxetanes (For a review, see W. Adam, In Chemical and Biological Generation of Excited States, W. Adam and G. Cilento, Eds. Ch. 4, Academic Press, New York, 1982). A. Paul Schaap application Serial No. 224,681, filed July 27, 1987 shows the use of fluorescers with triggerable dioxetanes.

Energy transfer in homogeneous solution, however, requires high concentrations of the energy acceptor because of the short lifetimes of the

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electronically excited species. These high concentrations can lead to problems of self-quenching and reabsorption. The present invention solves these problems by using a fluorescer which is chemically bound or tethered to the excited product produced by triggering the dioxetane, thereby obviating the need for high concentrations of a fluorescer in bulk solution.

(d) Enhanced Chemiluminescence from a Dioxetane Using Intramolecular Energy Transfer to a Tethered Fluorescer. No examples appear in the literature of a fluorescent energy acceptor that is chemically bound or tethered to a dioxetane. The only examples of enhanced chemiluminescence using intramolecular energy transfer derived from the work of White on the luminol system (M. A. Ribi, C. C. Wei, and E. H. White, Tetrahedron, 28 481 (1972) and references therein). Chemiluminescence is produced by chemical oxidation of phthalic hydrazides to form electronically excited phthalate ions followed by energy transfer to attached fluorescent groups. Dioxetanes are not involved in these processes.

(e) Enhanced Chemiluminescence from the Luminol/peroxidase Reaction. A method for enhancing the chemiluminescent yield of the luminol/peroxidase reaction by addition of 6-hydroxybenzothiazole derivatives or para-substituted phenols (G. H. G. Thorpe, L. J. Kricka, S. B. Moseley, T. P. Whitehead, Clin. Chem., 31, 1335 (1985); G. H. G. Thorpe and L. J. Kricka, Methods in Enzymology, 133, 331 (1986); and L. J. Kricka, G. H. G. Thorpe, and R. A. W. Scott, Pure & Appl. Chem., 59, 651 (1987)). The mechanism for the enhancement is not known but it does not involve intramolecular energy transfer with a chemically attached fluorescer.

#### OBJECTS

It is therefore an object of the present invention to provide novel dioxetanes which provide intramolecular transfer of energy to a tethered fluorescer molecule. Further, it is an object of the present

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invention to provide a process for the preparation of the novel dioxetanes. These and other objects will become increasingly apparent by reference to the following description and the drawings.

5 IN THE DRAWINGS

Figure 1 is a graph wherein curve A (---) shows the spectrum of direct chemiluminescence from chemical triggering of dioxetane 2b in DMSO with fluoride ( $\lambda_{\max} = 470$  nm); and curve B (\_\_\_) shows the spectrum of energy-transfer chemiluminescence from chemical triggering of tethered dioxetane 4b in DMSO with fluoride ( $\lambda_{\max} = 508$  nm).

Figure 2 is a graph wherein curve A (\_\_\_) shows the chemiluminescence spectrum from chemical triggering of tethered dioxetane 4b in DMSO with fluoride ( $\lambda_{\max} = 508$  nm); and curve B (---) shows the fluorescence spectrum of the cleavage product under the same conditions.

Figure 3 is a graph wherein curve A (\_\_\_) shows the spectrum of direct chemiluminescence from chemical triggering of dioxetane 2b in water with NaOH ( $\lambda_{\max} = 470$  nm; and curve B (---) shows the spectrum of energy-transfer chemiluminescence from chemical triggering of tethered dioxetane 6 in water with NaOH ( $\lambda_{\max} = 550$  nm).

Figure 4 is a graph wherein curve A (---) shows the spectrum of direct chemiluminescence from enzymatic triggering of dioxetane 2b in 221 buffer (pH 9.2) with aryl esterase ( $\lambda_{\max} = 470$  nm); and curve B (\_\_\_) shows the spectrum of energy-transfer chemiluminescence from enzymatic triggering of tethered dioxetane 4b in 221 buffer (pH 9.2) with aryl esterase ( $\lambda_{\max} = 519$  nm).

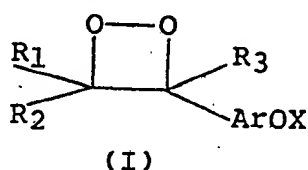
Figure 5 is a graph wherein curve A (\_\_\_) shows the chemiluminescence spectrum from enzymatic triggering of tethered dioxetane 4b in 221 buffer (pH 9.2) with aryl esterase ( $\lambda_{\max} = 519$  nm); and curve B (---) shows the fluorescence spectrum of the cleavage product under the same conditions.

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Figure 6 is a graph wherein curve A (\_\_\_\_) shows the chemiluminescence spectrum produced by enzymatic triggering with  $\beta$ -galactosidase of tethered dioxetane 8 in phosphate buffer (pH 7.2) followed by addition of 10N NaOH to induce the luminescence ( $\lambda_{\max} = 519$  nm); and curve B (---) shows the fluorescence spectrum of the cleavage product under the same conditions.

#### GENERAL DESCRIPTION

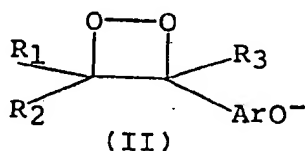
The present invention relates to a dioxetane compound of the formula:



wherein  $R_1$ ,  $R_2$  and  $R_3$  are carbon containing groups and optionally containing oxygen, nitrogen or sulfur which allow the production of the light,

wherein one of  $R_1$ ,  $R_2$  and  $R_3$  is a tethered fluorescent molecule containing group wherein the fluorescent molecule exhibits fluorescence between approximately 400 and 900 nanometers,

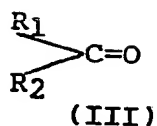
wherein  $R_1$  and  $R_2$  can be joined together,  
 wherein  $R_3$  and ArOX can be joined together,  
 wherein X is a leaving group,  
 wherein compound (I) decomposes to form an aryl oxide (II) of the formula



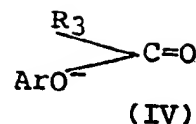
when reacted with an activating agent which removes X,  
 wherein the aryl oxide (II) spontaneously decomposes to form compounds (III) and (IV) of the

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formulae:



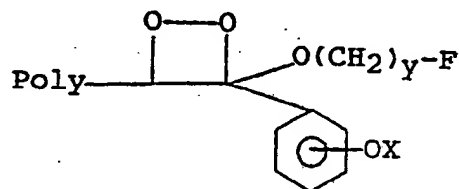
and



5 and wherein the fluorescent molecule in the fluorescent molecule containing group is activated to produce light upon the decomposition of the aryl oxide.

Further the present invention relates to a dioxetane compound of the formula:

10



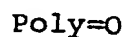
15

wherein Poly is a spirofused polycyclic alkylene group containing 6 to 30 carbon atoms and optionally oxygen and nitrogen,

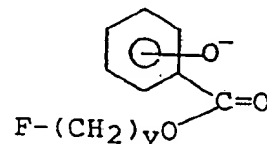
20 wherein F is a fluorescent molecule containing group wherein the fluorescent molecule exhibits fluorescence between 400 and 900 nanometers,

wherein y is an integer between 1 and 14, and

25 wherein X is a leaving group which when removed by an activating agent produces an oxide intermediate of the dioxetane compound which spontaneously decomposes to form light because of F and carbonyl containing molecules of the formulae



and



30

In particular the present invention relates to the compounds wherein OX is an acetoxy group, a hydroxyl group, an o-galactopyranoside group, or a phosphate group.

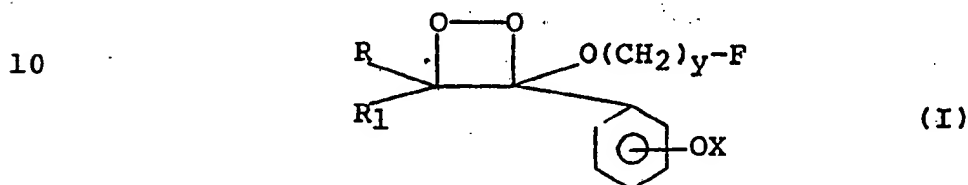
35 The fluorescent molecule can be selected from the group consisting of fluorescent dyes, aromatic compounds including benzene derivatives, naphthalene derivatives, anthracene derivatives, pyrenes, biphenyls,

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acridines, coumarins, xanthenes, phthalocyanines, stilbenes, furans, oxazoles, oxadiazoles, benzothiazoles, [fluoresceins], rhodamines, eosins, resorufins, quinolines. The fluorescent molecules are selected to provide

5 fluorescence in the range of about 400 to 900 nanometers.

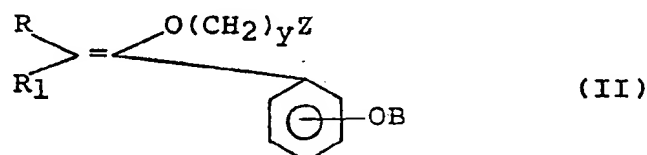
The preferred process for preparing the compounds generally involves the process for preparing a dioxetane compound (I) of the formula:



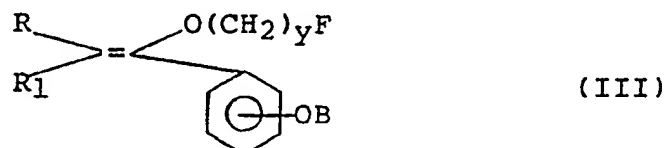
wherein R and R<sub>1</sub> are groups which allow the production of light and can be joined together, wherein y is an integer

15 between 1 and 14 and wherein F is a fluorescent molecule group, wherein X is a leaving group, which when removed by an activating agent produces an oxide intermediate of the dioxetane compound which spontaneously decomposes to form light because of F, which comprises: reacting in an organic

20 solvent, a compound (II) of the formula:



25 wherein Z is a reactive group, with FA wherein A is reactive with Z to form a compound (III) of the formula:

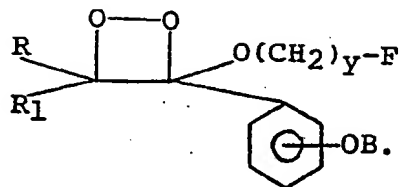


30 wherein B is a non-photo-oxidatively reactive group selected from the group consisting of X or groups which can be converted to X; and reacting oxygen with compound (III)

35

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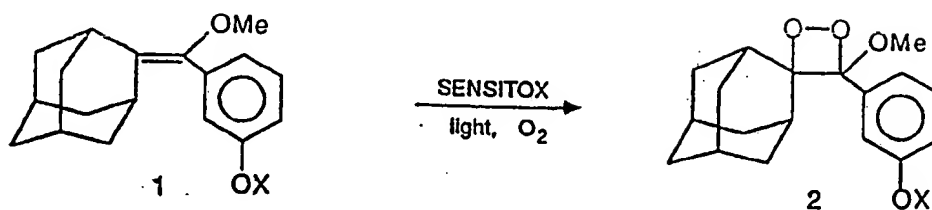
to form a dioxetane compound of the formula:



5 Preferably R and R<sub>1</sub> are joined together as a polycyclic group containing 6 to 30 carbon atoms. The OB (or OX) group can be acetoxy or other alkyl or aryl ester groups,  
 10 phosphate or other inorganic oxyacid salts, alkyl or aryl silyloxy, hydroxyl, oxygen-pyranoside such as beta-galactopyranosyl and the like.

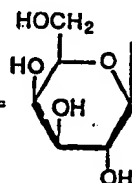
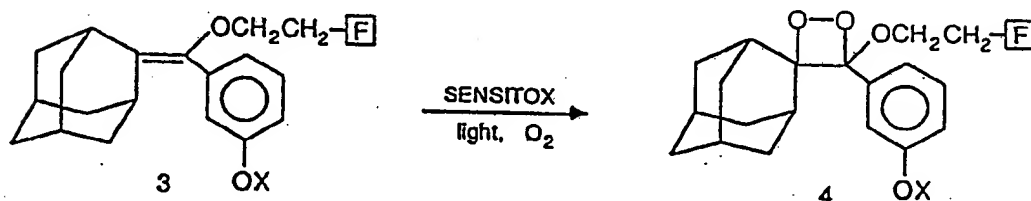
#### SPECIFIC DESCRIPTION

15 The following is a schematic of the compounds synthesized:

1,2-Dioxetane Compounds Synthesized

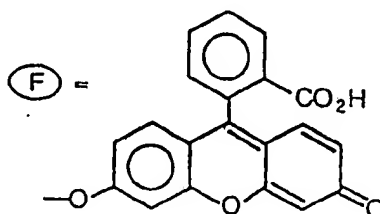
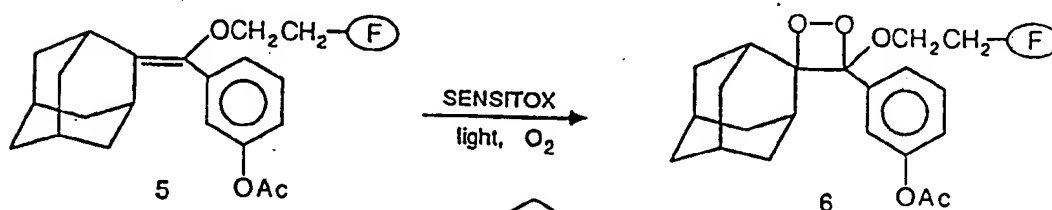
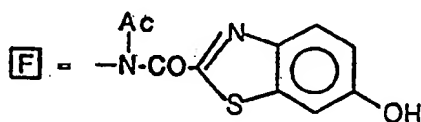
(a) X = H

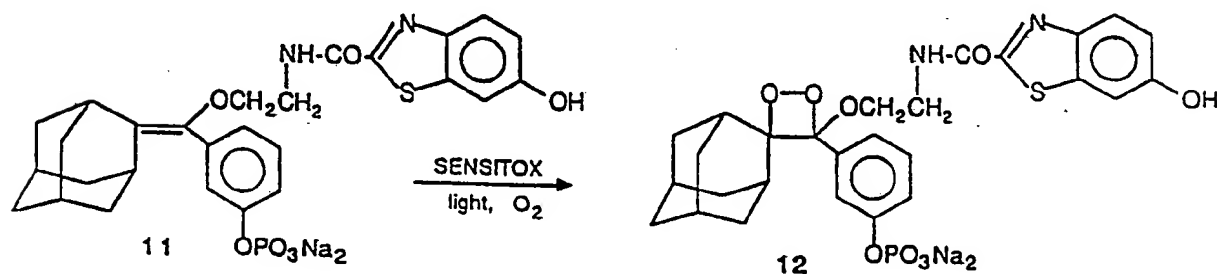
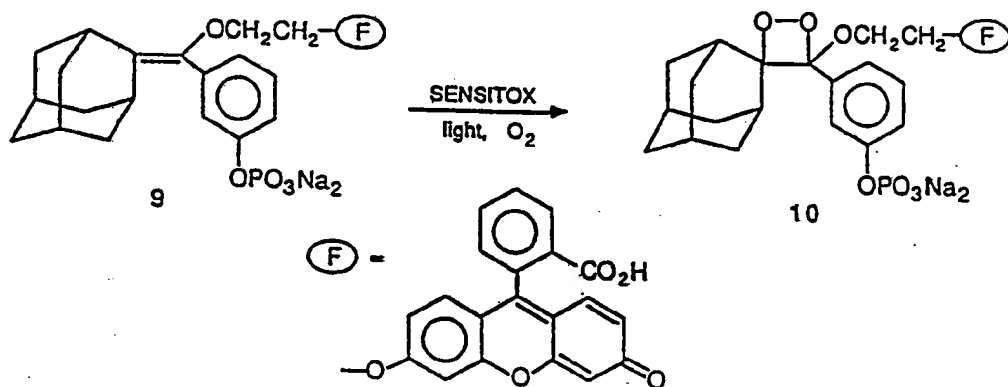
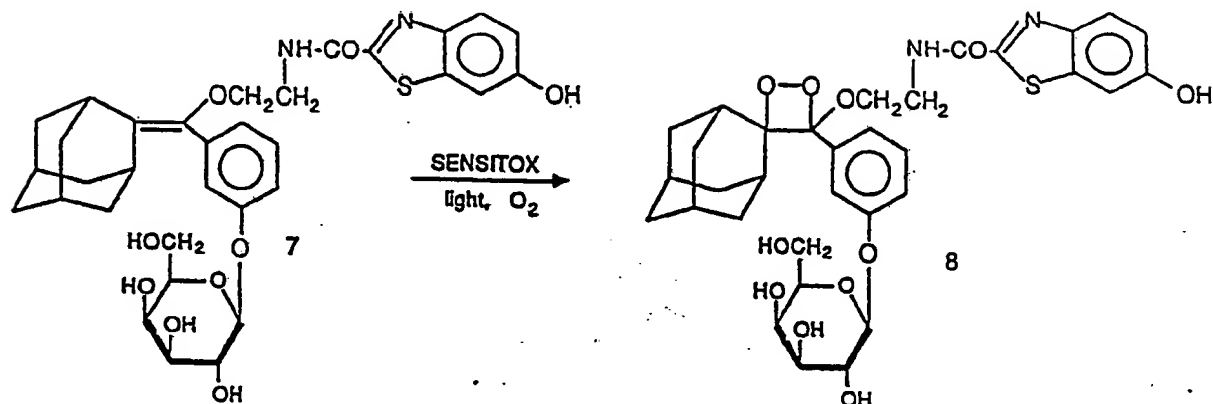
(b) X = Ac

(c) X =  $\beta$ -D-gactopyranosyl =(d) X =  $\text{OPO}_3\text{Na}_2$ 

(a) X = H

(b) X = Ac



1,2-Dioxetane Compounds Synthesized

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Instrumentation

Nuclear magnetic resonance (NMR) spectra were obtained on either a Nicolet NT300™ or a General Electric QE300™ spectrometer as solutions in CDCl<sub>3</sub> with tetramethylsilane as internal standard unless noted otherwise. Infrared (IR) spectra were obtained on either a Nicolet™ or a Beckman Acculab 8™ spectrometer. Mass spectra were obtained on either a Kratos™ or an AEI MS-90™ spectrometer. Ultraviolet and visible absorption spectra were obtained on a Varian Cary 219™ spectrophotometer. Fluorescence spectra were recorded on a Spex Fluorolog™ spectrophotofluorometer. Chemiluminescence spectra were measured using the Spex Fluorometer. Chemiluminescence kinetic and quantum yield measurements were made with luminometers constructed in this laboratory. The instruments which use RCA A-31034A gallium-arsenide photomultiplier tubes cooled to -78°C and Ortec photon-counting electronics are interfaced to Apple IIe™ and Macintosh™ computers. Elemental analyses were performed by Midwest Microlabs, Indianapolis. Melting points were measured in a Thomas Hoover™ capillary melting apparatus and are uncorrected. Precision weights were obtained on a Cahn model 4700™ electrobalance.

Materials

o-Xylene was obtained from Burdick and Jackson Laboratories and used as received for kinetic and spectroscopic measurements. Dry DMF and DMSO were obtained by vacuum distillation and calcium hydride. Deuterium oxide, 1,4-dioxane-d<sub>8</sub>, chloroform-d, and other chemical reagents were purchased from Aldrich Chemical Co. Samples of aryl esterase were purchased from Sigma Chemical Co. Silica, alumina, and the other solid supports were obtained from various commercial sources and used without further purification.

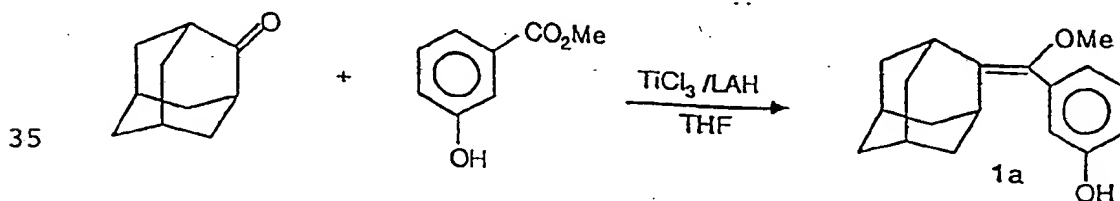
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Syntheses of Alkenes

[(3-Hydroxyphenyl)methoxymethylene]adamantane  
(1a) was prepared as described in my previous application  
Serial No. 224,681, filed July 27, 1988. A 500-mL flask  
5 was fitted with a reflux condenser, a 125-mL addition  
funnel, and nitrogen line. The apparatus was dried by  
means of a hot air gun and nitrogen purging. Dry THF (40  
mL) was added and the flask cooled in an ice bath.  $\text{TiCl}_3$   
(1.5 g, 10 mmol) was added rapidly followed by LAH (0.19 g,  
10 5 mmol) in portions with stirring. The cooling bath was  
removed and the black mixture was allowed to warm to room  
temperature. Triethylamine (0.7 mL, 5 mmol) was added to  
the stirred suspension and refluxed for 15 min. After this  
period, a solution of methyl 3-hydroxybenzoate (152 mg, 1  
15 mmol) and 2-adamantanone (300 mg, 2 mmol) in 20 mL of dry  
THF was added dropwise to the refluxing mixture over 15 min.  
Refluxing was continued for an additional 15 min after  
which the reaction was cooled to room temperature and  
diluted with 100 mL of distilled water. The aqueous  
20 solution was extracted with 3 x 50 mL portions of ethyl  
acetate. The combined organic layer was washed with water,  
dried over  $\text{MgSO}_4$ , and concentrated. Chromatography over  
silica with 15% ethyl acetate/hexane gave 240 mg (89%) of  
1a as a white solid: mp 133 - 4°C;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  1.64 -  
25 1.96 (m, 12H), 2.65 (s, 1H), 3.24 (s, 1H), 3.32 (s, 3H),  
5.25 (s, 1H, OH exchange with  $\text{D}_2\text{O}$ ), 6.70 - 7.30 (m, 4H);  
 $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ ) 28.45, 30.36, 32.36, 37.30, 39.18, 39.33,  
57.82, 114.60, 116.16, 122.19, 129.24, 137.24, 155.62; MS  
m/e (rel intensity) 271 (20, M + 1), 270 (100, M), 253  
30 (7.3), 213 (35.1), 121 (41.7) 93 (9.4); Exact mass: calcd  
270.1619, found 270.1616.

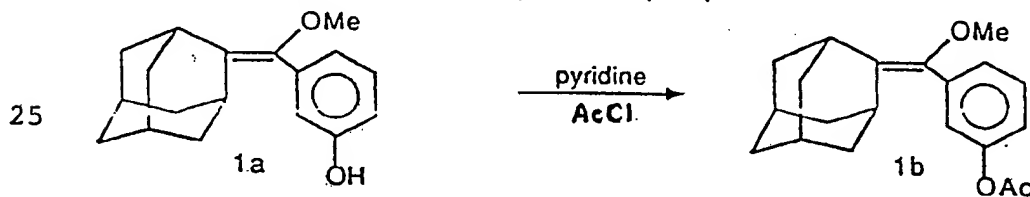


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[(3-Acetoxyphenyl)methoxymethylene]adamantane

(1b) was prepared as described in the previous application. Hydroxy alkene 1a (0.75g, 2.8 mmol) was dissolved in 10 mL of CH<sub>2</sub>Cl<sub>2</sub> and pyridine (5.2 g, 65.8 mmol) under N<sub>2</sub>. The solution was cooled in an ice bath and a solution of acetyl chloride (2.6 g, 33 mmol) in 1 mL of CH<sub>2</sub>Cl<sub>2</sub> was added dropwise via syringe. After 5 min at 0°C, TLC on silica with 20% ethyl acetate/hexane showed complete acetylation of 1a. After removal of the solvent, the solid residue was washed with 30 mL of ether. The ether was washed with 3 x 25 mL of water, dried over MgSO<sub>4</sub>, and evaporated to dryness. The product was chromatographed on silica using 20% ethyl acetate/hexane affording 0.45 g of 1b as an oil: <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 1.79 - 1.96 (m, 12H), 2.27 (s, 3H), 2.66 (s, 1H), 3.26 (s, 1H), 3.29 (s, 3H), 6.99 - 7.36 (m, 4H); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 20.90, 28.13, 30.07, 31.99, 36.99, 38.89, 39.01, 57.59, 120.34, 122.14, 126.55, 128.66, 132.19, 136.90, 142.59, 150.42, 169.04; MS m/e (rel intensity) 312 (100, M), 270 (25), 255 (19.3), 213 (20.7), 163 (12.2), 121 (30.7), 43 (30); IR (neat) 3006, 2925, 2856, 1725, 1600, 1438, 1362, 1218, 1100 cm<sup>-1</sup>; Anal. Calcd. for C<sub>20</sub>H<sub>24</sub>O<sub>3</sub>: C, 76.92; H, 7.69, Found: C, 76.96; H, 7.85.

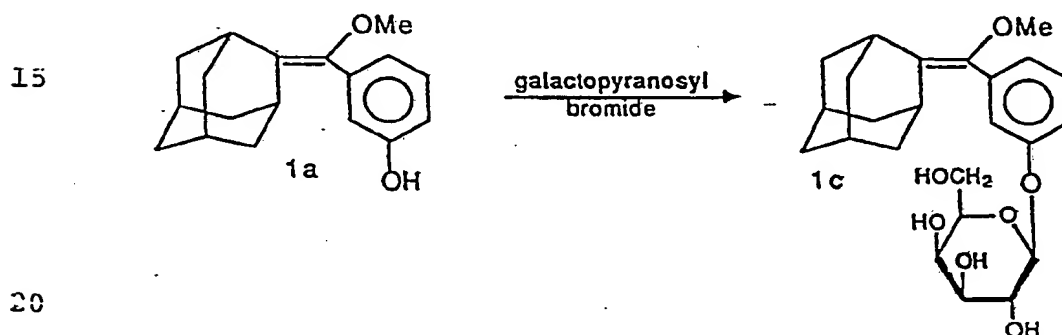
[(3-(-D-Galactopyranosyl)phenyl)methoxymethylene]adamantane(1c).

[(3-Hydroxyphenyl)methoxymethylene]adamantane (1a) (0.462 g, 1.12mmol) was dissolved in a minimum amount of acetone with a small amount 10 M KOH. After stirring the solution for 15 min, a solution of 2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl bromide in acetone was mixed with the alkene solution. The reaction was allowed to proceed overnight at room temperature. The acetone was then evaporated and the aqueous slurry was washed with water and extracted with ethyl acetate. The ethyl acetate fractions

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were combined and extracted with water, dried with  $\text{MgSO}_4$ , and evaporated to dryness. The solid product was recrystallized from a mixture of methylene/hexane to give 0.103 g (0.238 mmol, 62%) of a pale yellow solid:  $^1\text{H}$  NMR (dioxane- $d_8$ )  $\delta$  1.75-1.95 (m, 12H), 2.60 (s, 1H), 2.79 (s, 1H), 3.26 (s, 3H), 3.62-3.81 (m, 4H), 4.06 (d, 1H), 4.37 (d, 1H), 4.86 (d, 1H), 6.93-7.27 (m, 4H);  $^{13}\text{C}$  NMR (dioxane- $d_8$ )  $\delta$  13.59, 22.48, 28.45, 30.19, 31.47, 32.31, 37.13, 38.93, 39.08, 56.91, 61.42, 68.92, 71.39, 73.94, 75.84, 100.87, 115.28, 117.11, 123.01, 128.93, 131.03, 136.98, 143.74, 157.56; MS m/e (rel. intensity) 432 (15), 270 (100), 213 (10), 101 (17), 83 (13), 59 (47), 43 (96).



2-Cyano-6-hydroxybenzothiazole. Dry pyridinium hydrochloride (34.0 g, 0.294 mol) and 2-cyano-6-methoxy-benzothiazole (Aldrich Chemical Co., 3.0 g, 0.016 mol) were added into a 500 mL round bottom flask which was preheated in an oil bath at 100°C. The bath temperature was increased to 190°C and the reaction mixture was refluxed at this temperature for 2 h. After the completion of reaction, it was cooled to room temperature to obtain a yellow solid which was dissolved in methanol. Silica was added to this solution and evaporated to dryness. This material was then chromatographed using 30% ethyl acetate/hexane to obtain 2.7 g of the product as a white solid (95%): mp 120°C;  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  5.68 (bs, 1H), 8.02-8.82 (m, 3H);  $^{13}\text{C}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  106.96, 114.26, 119.59, 126.53, 133.83, 138.93, 147.25, 160.23; MS m/e (rel

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intensity) 176 (100), 151 (3), 124 (5), 96 (15), 85 (4), 69 (7), 57 (5); Exact mass: calcd 176.0044, found 176.0047.

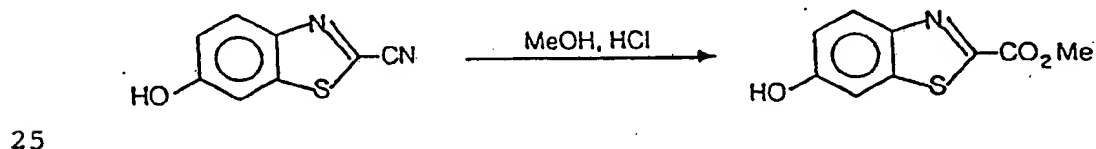


Methyl 6-hydroxy-2-benzothiazooate. Dry methanol (30 mL) was saturated with HCl by passing dry HCl gas for 10 min. To this solution was added

10 2-cyano-6-hydroxybenzothiazole (0.475 g, 0.0023 mol). The resulting yellow solution was stirred at room temperature for 4 days. After the end of this period, the product crystallized out of the solution as a yellow solid which was obtained by vacuum filtration, washed with water and

15 dried to yield the product as a white solid (0.565 g, 100%): mp 200°C; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 3.92 (2, 3H), 7.02-7.86 (m, 3H); <sup>13</sup>C NMR (CD<sub>3</sub>OD) δ 52.38, 105.88, 117.66, 124.98, 138.43, 146.18, 154.34, 158.12, 160.12; MS m/e (rel intensity) 209 (82), 178 (25), 151 (100), 123 (6), 106 (9),

20 95 (12), 85 (5), 69 (10), 59 (10), 51 (6), 45 (11); Exact mass: calcd 209.0146, found 209.0149.



Methyl (6-tert-butyldimethylsilyloxy)-2-benzothiazooate. To a solution of methyl 6-hydroxy-2-benzothiazooate (1.5 g, 0.007 mol) and tert-butyldimethylsilyl chloride (0.7 g, 0.011 mol) in 5 mL

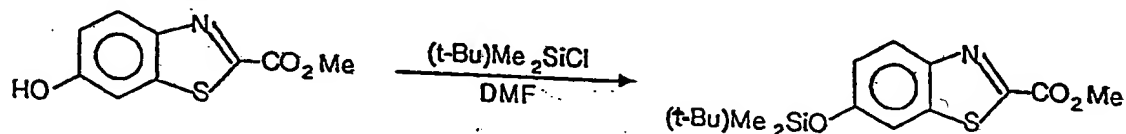
30 of dry DMF, was gradually added imidazole (0.980 g, 0.014 mol). The solution was then stirred overnight. TLC analysis (silica gel, 20% ethyl acetate/hexane) showed clean conversion to a new material. The solution was poured into 25 mL of water and extracted with 3x25 mL of

35 ether. The combined ether solutions were dried over anhydrous MgSO<sub>4</sub>. Evaporation of solvent gave an oil which was chromatographed on silica using 10% ethyl

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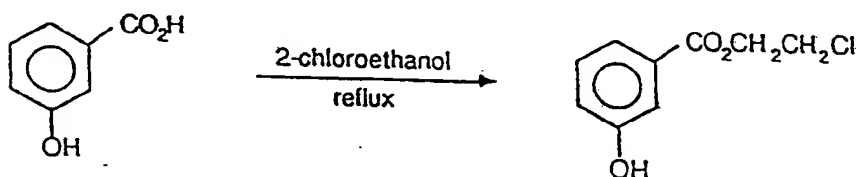
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acetate/hexane to give 2.2 g (96%) of the product as a colorless liquid:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  0.255 (s, 6H), 1.01 (s, 9H), 4.06 (s, 3H), 7.04 - 8.07 (m, 3H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  -5.07, 17.53, 24.95, 52.64, 110.77, 120.95, 125.45, 137.77, 147.61, 154.98, 155.15, 160.35.



- 10 2-Chloroethyl 3-hydroxybenzoate. A solution of 3-hydroxybenzoic acid (15.0 g, 0.11 mol) in 2-chloroethanol (70 mL, 1.0 mol) and 1 mL of concentrated sulfuric acid was refluxed for overnight. TLC analysis (silica gel/20% ethyl acetate/hexane) showed clean conversion to a new material.
- 15 The excess chloroethanol was removed by evaporation to obtain a brown solution which was dissolved in ethyl acetate and washed with water. The organic layer was dried with  $\text{MgSO}_4$  and concentrated to obtain 21.0 g of the product as a white solid: mp  $50^\circ\text{C}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  3.81 (t, 2H, J=5.9 MHz), 4.57 (t, 2H, J=5.9 MHz), 4.77 (s, 1H), 7.06-7.66 (m, 4H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  41.52, 64.75, 116.43, 120.77, 121.98, 129.80, 130.71, 156.04, 166.57; MS m/e (rel intensity) 200 (26), 138 (59), 121 (100), 93 (31), 65 (21), 39 (12); Exact mass: calcd 200.0240, found 200.0242.

23

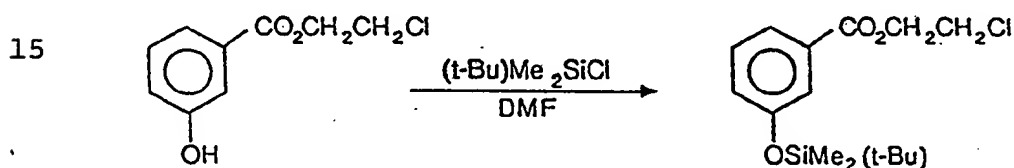


30

- 2-Chloroethyl 3-(tert-butyldimethylsilyloxy)benzoate. To a solution of 2-chloroethyl 3-hydroxybenzoate (4.0 g, 0.02 mol) and tert-butyldimethylsilyl chloride (4.5 g, 0.029 mol) in 5 mL of dry DMF was gradually added imidazole (92.7 g, 0.04 mol). The solution was then
- 35 stirred overnight. TLC analysis (silica gel, 20% ethyl acetate/hexane) showed clean conversion to a new material. The solution was poured into a 25 mL of water and extracted

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with 3x25 mL of ether. The combined ether solutions were dried over anhydrous  $\text{MgSO}_4$ . Evaporation of the solvent gave an oil which was chromatographed on silica using 10% ethyl acetate/hexane to give the product quantitatively as a colorless liquid:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  0.218 (s, 6H), 0.994 (s, 9H), 3.81 (t, 2H,  $J=5.7$  MHz), 4.56 (t, 2H,  $J=5.7$  MHz), 7.05-7.65 (m, 4H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  -4.97, 17.66, 25.12, 41.06, 63.91, 120.61, 122.19, 124.60, 128.95, 130.53, 155.31, 165.35; MS  $m/e$  (rel intensity) 314 (14), 257 (9), 235 (9), 213 (100), 185 (6), 149 (7), 135 (10), 120 (6), 93 (13), 83 (6), 69 (9), 55 (9); Exact mass: calcd 314.1104, found 314.1110.

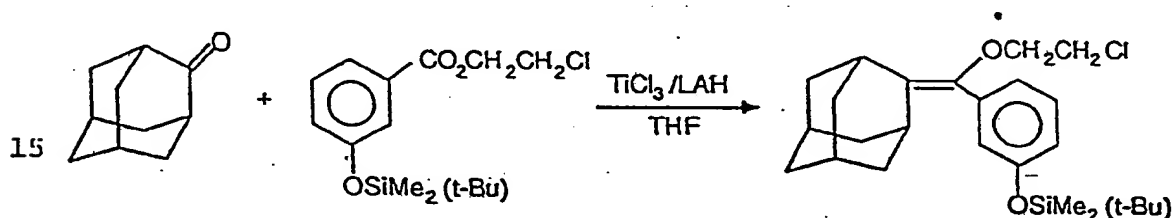


20 -(3-tert-Butyldimethylsilyloxy  
phenyl)(2-chloroethyl)methylene]adamantane. A 100 mL  
 three-necked flask fitted with a reflux condenser, was  
 dried by means of a hot air gun and nitrogen purging. This  
 was charged with dry THF 200 mL and cooled in an ice-bath.  
 25 Titanium trichloride (24.5 g, 0.16 mol) followed by lithium  
 aluminum hydride (3.0 g, 0.08 mol) in portions with  
 vigorous stirring. The cooling bath was removed and the  
 black mixture was allowed to warm to room temperature.  
 Triethylamine (15 mL) was added dropwise and the reaction  
 30 mixture was refluxed for 1 h. A solution of 2-chloroethyl  
 3-(tertbutyldimethylsilyloxy)benzoate (5.0 g, 0.015 mol)  
 and 2-adamantanone (7.1 g, 0.05 mol) was added dropwise to  
 the refluxing mixture over a 1 h period. TLC analysis  
 (silica gel 10% ethyl acetate/hexane) after 1 h of  
 35 refluxing showed conversion to a new material. The  
 reaction mixture was cooled, extracted with hexane. After  
 the evaporation of solvent, the crude material was

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chromatographed using 3% ethyl acetate/hexane to give 5.0 g (74%) of the product as a white oil:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  0.194 (s, 6H), 0.982 (s, 9H), 1.78-1.98 (m, 12H), 2.65 (s, 1H), 3.34 (s, 1H), 3.55 (t, 2H,  $J=5.7$  MHz), 3.66 (t, 2H,  $J=5.7$  MHz), 6.85-7.29 (m, 4H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  -4.46, 18.21, 25.66, 28.28, 30.20, 32.39, 38.94, 39.20, 42.61, 68.95, 119.62, 121.04, 122.50, 129.09, 132.78, 136.40, 141.11, 155.49; MS m/e (rel intensity) 432 (100), 331 (22), 235 (13), 199 (10), 151 (19), 105 (17), 73 (44), 57 (14); Exact mass: calcd 432.2251, found: 432.2247.



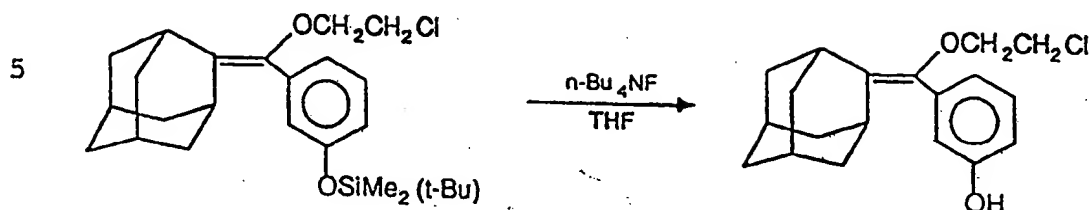
[(2-Chloroethoxy)(3-hydroxyphenyl)methylene]

20 adamantane. To a stirred solution of the tert-butyldimethylsilyl protected-alkene shown above (2.0 g, 0.004 mol) in 5 mL of THF was added tetrabutylammonium fluoride trihydrate (1.4 g, 0.004 mol) and the resulting solution was stirred for 10 min. TLC analysis (silica gel, 25 20% ethyl acetate/hexane) indicated conversion to a new material. After evaporation of solvent, the crude product was washed with water and taken up in ether. The organic layer was dried over  $\text{MgSO}_4$  and evaporated to dryness. The oily material was chromatographed on silica gel using 20% 30 ethyl acetate/hexane to give 1.3 g (100%) of the product:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  1.81-1.96 (m, 12H), 2.67 (s, 1H), 3.34 (s, 1H), 3.55 (t, 2H,  $J=5.6$  MHz), 3.69 (t, 2H,  $J=5.6$  MHz), 6.77-7.19 (m, 4H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  28.21, 30.24, 32.35, 37.08, 38.92, 39.19, 42.55, 69.05, 114.76, 116.05, 121.92, 35 129.31, 133.41, 136.62, 140.77, 155.64; MS m/e (rel intensity) 318 (100), 227 (19), 213 (24), 121 (92), 107

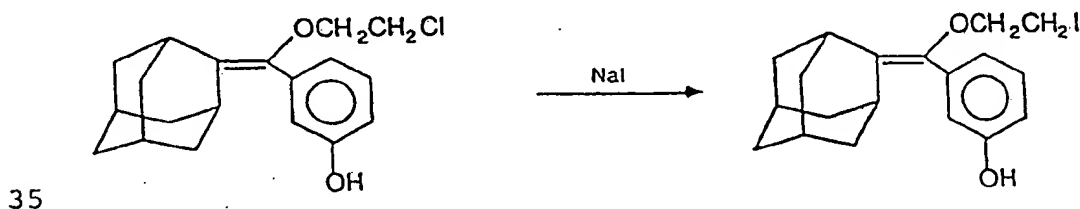
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(29), 93 (37), 69 (21), 55 (36), 41 (40); Exact mass; calcd 318.1386, found 318.1383.



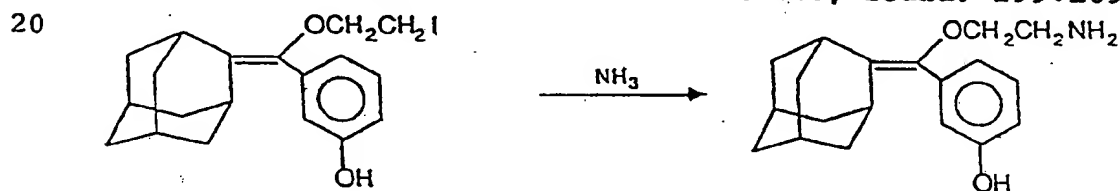
[(3-Hydroxyphenyl)(2-iodoethoxy)methylene]  
adamantane. Sodium iodide (14.0 g, 0.09 mol) and  
 [(2-chloroethoxy)(3-hydroxyphenyl)methylene]adamantane (3.0  
 15 g, 0.009 mol) were dissolved in dry acetone and refluxed  
 for 6 days. The reaction was followed by TLC analysis  
 (silica gel, 10% ethyl acetate/hexane) and after the  
 completion of reaction, solvent was evaporated to obtain a  
 white solid. This solid was washed with methylene chloride  
 20 several times and the combined organic layers were again  
 washed with water. The organic layer was dried over  $\text{MgSO}_4$   
 and concentrated to give 3.8 g (100%) of product as an oily  
 material:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  1.78–1.97 (m, 12H), 2.64 (bs,  
 1H), 3.19 (t, 2H,  $J=7.1$  MHz), 3.35 (bs, 1H), 3.69 (t, 2H,  
 25  $J=7.1$  MHz), 6.75–7.21 (m, 4H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  2.40,  
 28.13, 30.41, 32.33, 36.99, 38.86, 39.09, 69.74, 114.86,  
 116.00, 121.79, 129.28, 133.37, 136.42, 140.51, 155.66. MS  
 m/e (rel intensity) 410 (42), 256 (19), 227 (75), 155 (18),  
 121 (100), 107 (32), 93 (28), 79 (14), 65 (16); Exact mass:  
 30 calcd 410.0744, found: 410.0744.



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[(2-Aminoethoxy)(3-hydroxyphenyl)methylene]  
adamantane. A solution of  
 [(3-hydroxyphenyl)(2-iodoethoxy)methylene]adamantane (3.0  
 g, 0.01 mol) in a minimum amount of THF was added into 10  
 5 mL of liquid ammonia in a sealed tube which was kept in dry  
 ice. After sealing the tube this was heated at 40°C in an  
 oil bath for 17 h. The reaction mixture was cooled down  
 and solvent evaporated to obtain a white solid. This  
 material was extracted with methylene chloride. The  
 10 combined organic layers were washed with water, dried over  
 MgSO<sub>4</sub>, and concentrated to give 2.0 g (90%) of the product  
 as a white solid: mp 55°C; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 1.77-1.96 (m,  
 12H), 2.68 (bs, 1H), 2.85 (t, 2H, J=4.8 MHz), 3.23 (bs,  
 1H), 3.48 (t, 2H, J=4.8 MHz), 4.46 (bs, 2H), 6.70-7.17 (m,  
 15 4H); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 28.16, 30.28, 32.19, 36.99, 38.88,  
 39.04, 41.33, 70.45, 114.97, 116.17, 120.63, 129.02,  
 131.89, 136.69, 141.79, 156.86; MS m/e (rel intensity) 299  
 (10), 256 (100), 239 (5), 199 (6), 135 (12), 121 (27), 93  
 (12), 77 (5). Exact mass: calcd 299.1885, found: 299.1891.



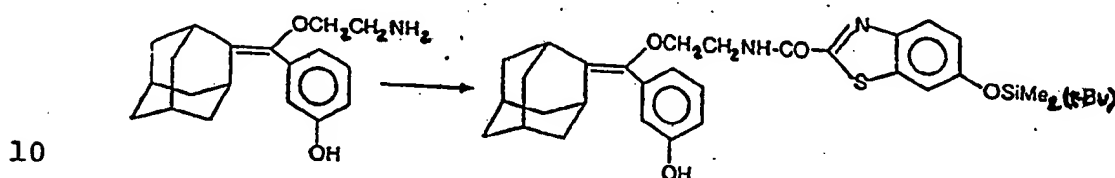
[[2-(N-(6-tert-Butyldimethylsilyloxybenzo  
 25 thiazole-2-carbonyl)amino)ethoxy][3-hydroxyphenyl]  
methylene]adamantane.

Methyl 6-tert-butyldimethylsilyloxy-2-benzothiazooate (1.2  
 g, 0.004 mol) and  
 [(2-aminoethoxy)(3-hydroxyphenyl)methylene]adamantane (3.3  
 30 g, 0.011 mmol) were dissolved in dry methanol and refluxed  
 gently with trace of NaHCO<sub>3</sub>. After 4 days, completion of  
 the reaction was indicated by NMR. After evaporation of  
 the solvent, the crude material was chromatographed using  
 silica gel and 20% ethyl acetate/hexane to yield 60 mg  
 35 (88%) of the product as a white solid: mp 105°C; <sup>1</sup>H NMR  
 (CDCl<sub>3</sub>) δ 0.158 (s, 6H), 0.945 (s, 9H), 1.79-1.97 (m, 12H),  
 2.65 (bs, 1H), 3.32 (bs, 1H), 3.64 (m, 4H), 6.73-7.38 (m,

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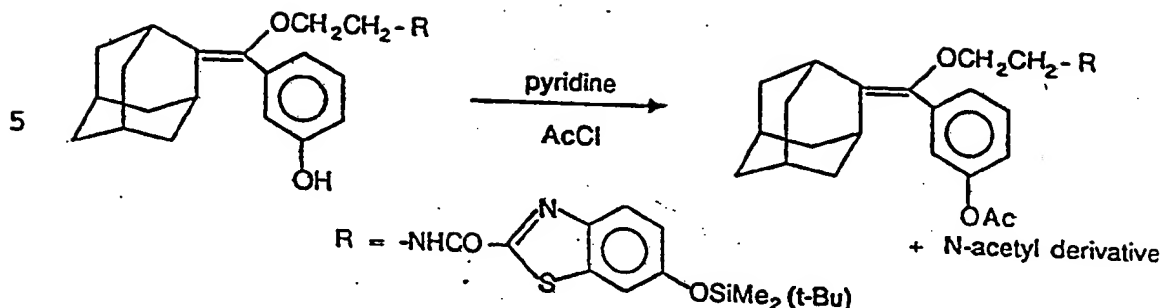
-31-

7H), 7.76 (bs, 1H), 7.95 (t, 1H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ ):  $\delta$  -4.59, 15.02, 25.51, 28.16, 30.34, 32.26, 37.00, 38.39, 39.03, 39.89, 67.42, 106.91, 117.34, 119.54, 120.96, 122.32, 124.96, 129.13, 136.29, 138.77, 141.54, 146.94, 155.39, 156.46, 159.59, 160.34, 160.49.



{[3-Acetoxyphenyl][2-(N-(6-tert-butyl dimethyl silyloxybenzothiazole-2-carbonyl)amino)ethoxy]methylene}  
 15 adamantane. The corresponding hydroxy alkene shown above (60 mg, 0.01 mmol) was dissolved in 1 mL of methylene chloride and 300  $\mu\text{L}$  of pyridine under nitrogen. This solution was cooled in an ice bath and 36  $\mu\text{L}$  of acetyl chloride (39 mg, 0.5 mmol) was added dropwise via a syringe.  
 20 After stirring this solution for 1 hr at 0°C, TLC (silica gel, 20% ethyl acetate/hexane) indicated completion of the reaction. After removal of solvent in vacuo, the solid residue was dissolved in ether and washed with water. The ether layer was dried over  $\text{MgSO}_4$  and concentrated to obtain  
 25 an oily material. This material was chromatographed on silica using 15% ethyl acetate and hexane to obtain an inseparable mixture (9:1) of the NH alkene and N-acetylated alkene. Spectral data for the NH alkene:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  0.165 (s, 6H), 0.95 (s, 9H), 1.8-1.97 (m, 12H), 2.17 (s, 3H), 2.36 (bs, 1H), 2.65 (bs, 1H), 3.34 (bs, 1H), 3.65 (m, 4H), 6.73-8.07 (m, 7H), 7.79 (bs, 1H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  -4.48, 18.16, 21.05, 25.63, 28.30, 30.45, 32.44, 37.12, 39.02, 39.16, 39.93, 67.56, 115.01, 119.61, 121.08, 121.52, 122.41, 124.92, 129.19, 132.19, 136.48, 137.86, 141.72,  
 30 149.28, 150.83, 155.52, 159.64, 164.12, 169.21

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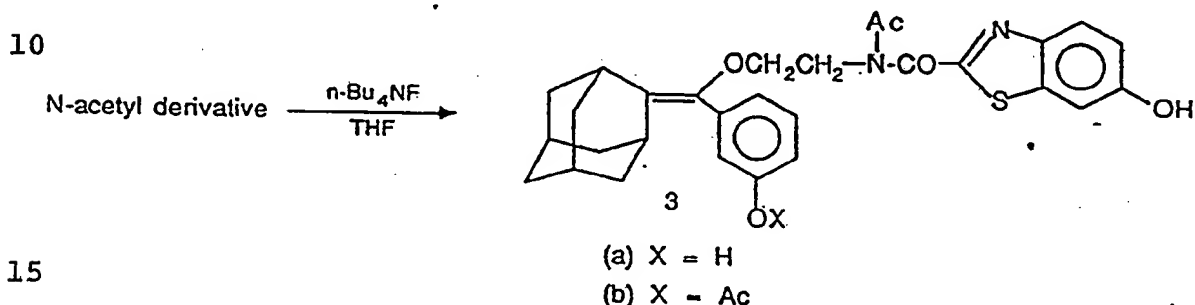
10 {[2-(N-Acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)  
ethoxy][3-hydroxyphenyl]methylene}adamantane (3a) and  
{[3 Acetoxyphenyl][2-(N-acetyl-N-(6-hydroxybenzothiazole-2-  
carbonyl)amino)ethoxy]methylene}adamantane (3b). To a cold  
 15 of THF was added a solution of tetrabutylammonium fluoride  
 trihydrate (49 mg, 0.16 mmol) in 0.5 mL of THF via a  
 syringe. TLC analysis after the addition (silica gel, 1:1  
 ethyl acetate/hexane) showed the formation of three  
 products. After the evaporation of the solvent, the crude  
 20 product was washed with water, dried over  $\text{MgSO}_4$ , and  
 concentrated. The crude oily material was chromatographed  
 on silica using ethyl acetate and hexane to obtain three  
 products. The first product was obtained with 25% ethyl  
 acetate/hexane and identified as alkene (3b):  $^1\text{H}$  NMR  
 25 ( $\text{CDCl}_3$ )  $\delta$  1.81-1.98 (m, 12H), 2.18 (s, 3H), 2.37 (s, 3H),  
 2.68 (bs, 1H), 3.34 (bs, 1H), 3.65 (m, 4H), 6.97-8.79 (m,  
 7H), 7.77 (bs, 1H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  20.96, 21.04, 28.23,  
 30.55, 32.34, 37.07, 39.03, 39.16, 39.94, 67.81, 104.9,  
 115.03, 120.77, 121.54, 122.36, 124.88, 126.65, 129.08,  
 30 131.34, 133.43, 133.53, 136.69, 141.04, 149.31, 150.68,  
 159.60, 169.21.

The second product was obtained with 35% ethyl  
 acetate/hexane and was found to be  
 {[2-(N-acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)  
 35 ethoxy][3-hydroxyphenyl]methylene}adamantane (3a):  $^1\text{H}$  NMR  
 ( $\text{CDCl}_3$ )  $\delta$  1.80-1.96 (m, 12H), 2.18 (s, 3H), 2.67 (bs, 1H),

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3.33 (bs, 1H), 3.65 (m, 4H), 6.74 (bs, 1H), 6.96-7.92 (m, 7H), 7.79 (bs, 1H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  20.97, 28.22, 30.53, 32.35, 37.07, 39.01, 39.14, 39.97, 67.79, 107.09, 117.16, 120.75, 122.35, 125.13, 126.71, 129.10, 133.50, 136.72, 138.86, 140.98, 147.39, 150.65, 155.72, 160.34, 160.43, 169.36. The third product was identified as

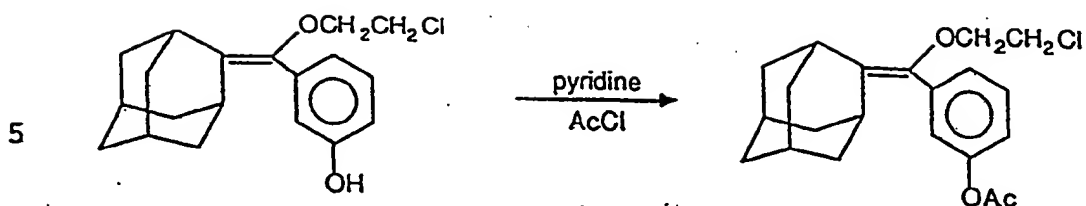
[[2-(N-(6-hydroxybenzothiazole-2-carbonyl)amino)ethoxy] [3-hydroxyphenyl]methylene]adamantane



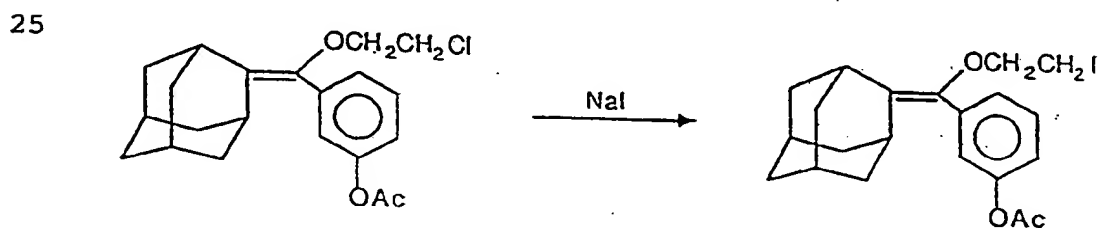
[[3-Acetoxyphenyl]92-chloroethoxy)methylene] adamantane. The corresponding hydroxy alkene (1g, 3.13 mmol) was dissolved in 15 mL of methylene chloride and pyridine (5 mL, 63 mmol) under  $\text{N}_2$ . The solution was cooled in an ice bath and a solution of acetyl chloride (0.25 g, 3.13 mmol) in 1 mL of methylene chloride was added dropwise by a syringe. A white precipitate formed. After two h at 0-5°C, TLC with 10% ethyl acetate/hexane) showed complete acetylation. After removal of the solvent in vacuo, the solid residue was washed with 100 mL of hexane. The hexane was washed with 2 x 50mL of water, dried over  $\text{MgSO}_4$  and evaporated to dryness. The oily material was chromatographed on silica using 10% ethyl acetate/hexane to give the product (0.91 g, 2.52 mmol, 80%):  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  1.70-2.00 (m, 12H), 2.30 (s, 3H), 2.67 (s, 1H), 3.50 (s 1H), 3.54 - 3.58 (t, 2H), 3.67 - 3.69 (t, 2H), 7.00 - 7.40 (m, 4H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  21.11, 28.19, 30.27, 32.28, 37.07, 38.92, 39.17, 42.62, 69.22, 120.76, 122.32, 126.70, 129.02, 133.93, 136.64, 140.40, 150.59, 169.28.

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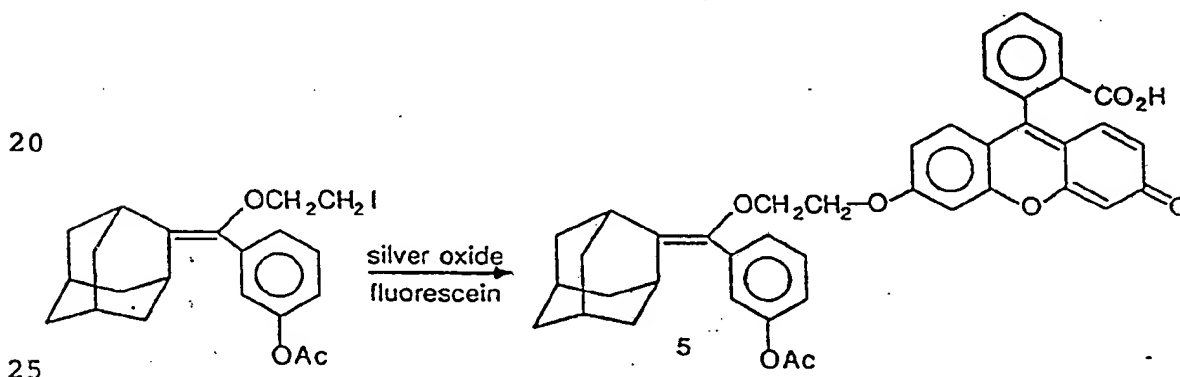
[(3-Acetoxyphenyl)(2-iodoethoxy)methylene]adamantane. To a solution of the chloroalkene (0.4 g, 2.49mmol) in 10 mL of dry acetone was slowly added anhydrous sodium iodide. The solution was refluxed for four days in the dark. TLC analysis on silica with 10% ethylacetate/hexane showed clean conversion to a new, less polar material. Evaporation of the solvent gave a white solid which was washed with hexane. The hexane solution was evaporated to give the product as a colorless oil (1.11g, 2.45 mmol, 98%): <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 1.70–2.00 (m, 12H), 2.30 (s, 3H), 2.65 (s, 1H), 3.17 – 3.21 (t, 2H), 3.36 (s, 1H), 3.66 – 3.70 (t, 2H), 6.99 – 7.4 (m, 4H); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 21.14, 28.21, 30.51, 32.33, 37.10, 38.96, 39.18, 69.94, 116.32, 120.79, 122.34, 126.72, 129.04, 133.93, 136.63, 140.39, 150.60, 169.28.



[(3-Acetoxyphenyl)(2-(O-fluorescein)ethoxy)-methylene]adamantane(5). The iodoalkene (1g, 2.21 mmol), fluorescein (1.47 g, 4.42 mmol), and silver oxide (5 g,

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21.6 mmol) were placed in a 50 mL round-bottom flask containing 20 mL of dry benzene. The resulting yellow suspension was refluxed in the dark for 24 h. After cooling, the solid silver oxide and silver iodide were  
 5 filtered off and the filtrate was evaporated to dryness under vacuum. The yellow solid was chromatographed over silica with 20% ethyl acetane/benzene to give the pure product as a yellow solid (1.09 g, 1.66 mmol, 75%):  $^1\text{H}$  NMR (p-dioxane - dg)  $\delta$  1.69 - 1.95 (m, 12H), 2.22 (s, 3H), 2.64  
 10 (s, 1H), 3.33 (s, H), 3.7 - 3.79 (s, 2H), 4.00 - 4.1 (s, 2H), 6.40 - 8.20 (m, 14H);  $^{13}\text{C}$  NMR (p-dioxane-dg) 20.63, 28.48, 30.85, 33.06, 37.64, 39.37, 39.68, 67.94, 67.67, 82.76, 101.95, 103.12, 112.56, 112.73, 112.92, 121.44, 123.17, 124.39, 125.40, 127.21, 127.73, 128.93, 129.52,  
 15 129.72, 129.97, 133.49, 135.20, 137.53, 141.81, 151.74, 152.91, 153.01, 154.48, 159.59, 161.29, 169.10.

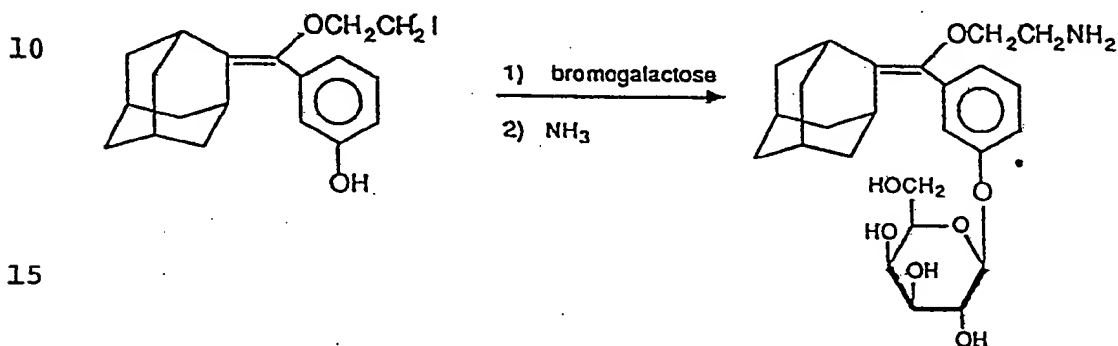


[(2-Aminoethoxy)(3- $\beta$ -D-galactopyranosylphenyl)methyleneladamantane]. Acetobromo- $\alpha$ -D-galactose (5g, 1.2 mmol) was slowly added to a solution of  
 [(3-hydroxyphenyl)(2-iodoethoxy)methyleneladamantane (1g,  
 30 0.24mmol) in 1:1 5N KOH and acetone (5mL). This mixture was stirred at room temperature for 10 min. TLC analysis (silica gel, 50% ethyl acetate/hexane) indicated formation of five new compounds due to the partial deacetylation. After evaporation of the solvent, the crude material was  
 35 washed with water and evaporated to dryness. This material was dissolved in a minimum amount of THF and added into 20mL of liquid ammonia in a tube. After sealing the tube,

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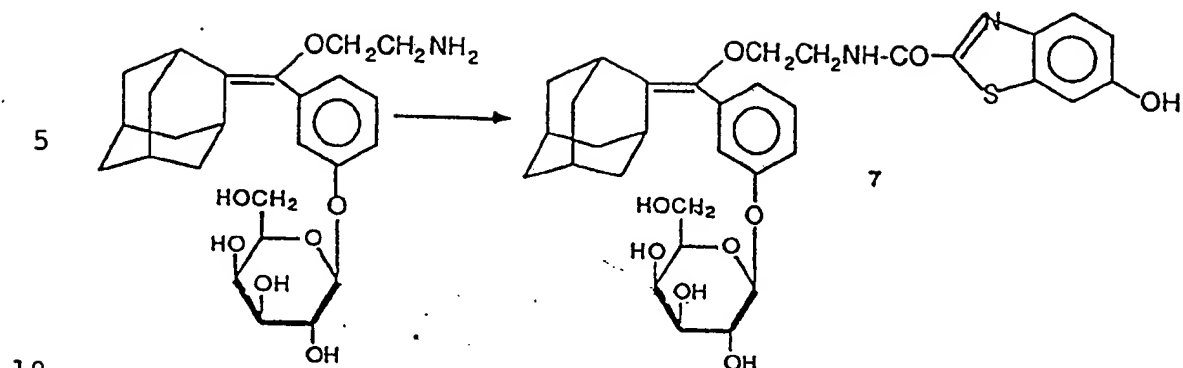
this solution was heated at 40°C in an oil bath for 17 h. The reaction mixture was cooled down and the solvent evaporated to obtain a white solid which was extracted with ethyl acetate. The combined organic layers were washed  
 5 with water, dried over  $\text{MgSO}_4$ , and concentrated to give 800mg (73%) of the product as a white solid. This material was carried on to the next step without further purification.



{[2-(N-(6-hydroxybenzothiazooate-2-carbonyl)amino)ethoxy][3- $\beta$ -D-galactopyranosylphenyl]methylene}adamantane (7).

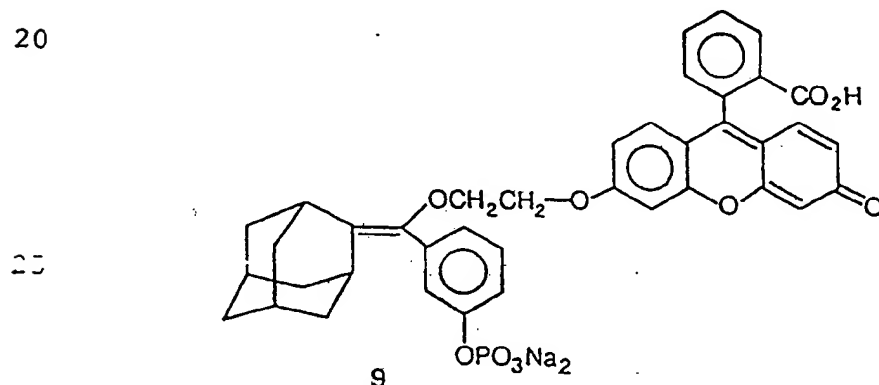
20 Methyl 6-tert-butylidimethylsilyloxy-2-benzothiazooate (363mg, 0.17mmol) and the product from previous reaction (800mg, 0.17mmol) were dissolved in dry methanol and refluxed gently with trace of  $\text{NaHCO}_3$ . After evaporation of the solvent, the crude material was washed with water and  
 25 taken up in ethyl acetate. This solution was concentrated to give a white solid which was chromatographed using silica gel and 100% acetone to yield 800mg (80%) of 7 as a white solid: mp 65°C;  $^1\text{H}$  NMR (acetone- $d_6$ )  $\delta$  1.65-1.88 (m, 12H), 2.6 (s, 1H), 3.3 (s, 1H), 3.6-4.01 (m, 10H), 4.94 (d, 1H), 6.5 (bs, 1H), 6.91-7.89 (m, 7H), 8.19 (s, 1H);  $^{13}\text{C}$  NMR (acetone- $d_6$ ):  $\delta$  28.19, 28.90, 30.16, 30.22, 32.24, 32.49, 36.83, 38.65, 38.82, 39.53, 61.25, 67.35, 68.82, 71.16, 73.73, 75.27, 101.11, 106.79, 115.79, 117.06, 117.14, 122.82, 124.91, 129.03, 131.49, 136.49, 138.49, 141.96,  
 30 146.77, 157.10, 157.60, 159.96, 160.45.  
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[(3-Phosphatephenyl)(2-(O-fluorescein)ethoxy)methyleneladamantane (9) and [(2-(N-(6-hydroxybenzothiazate-2-carbonyl)amino)ethoxy)[3-phosphatephenyl)methylene}adamantane, disodium salt (11) are prepared from

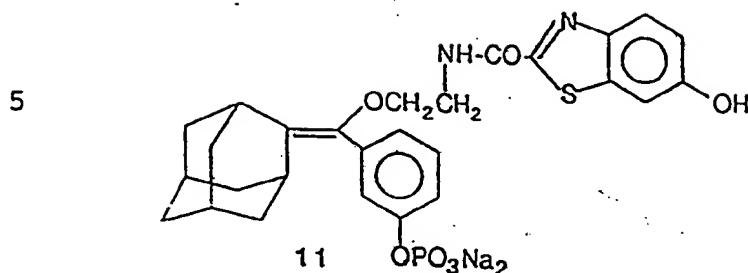
15. the correspondding hydroxy-substituted compounds using phosphorylation procedures described in my previous application Serial No. 224,681, filed July 27, 1988.



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### Preparation of 1,2-dioxetanes

Photooxygenation procedure. Typically a 5-10 mg sample of the alkene was dissolved in 5 mL of methylene chloride in the photooxygenation tube. Approximately 40 mg of polystyrene-bound Rose Bengal (Sensitox I) [reference to this type of sensitizer: A. P. Schaap, A. L. Thayer, E. C. Blosssey, and D. C. Neckers, *J. Amer. Chem. Soc.*, 97, 3741 (1975)] was added and an oxygen bubbler connected. Oxygen was passed slowly through the solution for 5 min and the apparatus immersed in a half-silvered Dewar flask containing dry ice/2-propanol. The sample was irradiated with a 1000 W high pressure sodium lamp (General Electric Lucalox) and a UV cutoff filter while oxygen was bubbled continuously. Progress of the reaction was monitored by TLC. A spot for the highly stable dioxetanes could usually be detected and had a  $R_f$  slightly less than that of the alkene. The adamantyl-substituted dioxetanes were filtered at room temperature, evaporated on a rotary evaporator, and recrystallized from a suitable solvent.

30

4-(3-Hydroxyphenyl)-4-methoxyspiro[1,2-dioxetane -3,2'-adamantane](2a). Hydroxy alkene 1a (100 mg) was irradiated with a 1000W sodium lamp in 8 mL of methylene chloride at  $-78^\circ\text{C}$  in the presence of Sensitox. The alkene and dioxetane on TLC using 20% ethyl acetate/hexane exhibit the same  $R_f$  value. Therefore, the reaction was stopped when a trace of the cleavage product began to appear. The

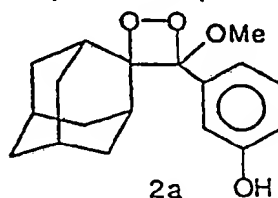
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sensitizer was removed by filtration and the solvent evaporated.  $^1\text{H}$  NMR was used to check that all of the starting material had been oxidized. Dioxetane 2a was recrystallized from pentane/benzene to give a white solid:

5 mp 135°C:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  1.04 - 2.10 (m, 12H), 2.21 (s, 1H), 3.04 (s, 1H), 3.24 (s, 3H), 6.48 (s, 1H, OH exchange with  $\text{D}_2\text{O}$ ), 6.93 - 7.30 (m, 4H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  25.81, 25.95, 31.47, 31.57, 32.27, 32.86, 33.07, 34.58, 36.30, 49.83, 95.88, 112.08, 116.46, 129.34, 136.1, 156.21.

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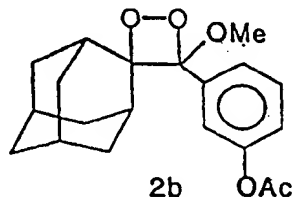
2a  
4-(3-Acetoxyphenyl)-4-methoxyspiro[1,2-

15 dioxetane-3,2'-adamantane](2b). Alkene 1b (140 mg, 0.45 mmol) was photooxygenated in 30 mL of methylene chloride at -78°C with a 1000 W sodium lamp using 400 mg of Sensitox. TLC analysis on silica gel with 20% ethyl acetate/hexane) showed clean conversion to a more polar material in 2.5 h.

20 Filtration and removal of solvent produced 2b as an oil:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  0.90 - 1.90 (m, 12H), 2.15 (2, 1H), 2.31 (s, 3H), 3.03 (s, 1H), 3.23 (s, 3H), 3.61 - 7.45 (m, 4H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  21.00, 25.82, 25.97, 31.50, 31.65, 32.21, 32.80, 33.09, 34.71, 36.32, 49.92, 95.34, 111.50, 122.58,

25 129.16, 136.42, 150.72, 169.11.

30



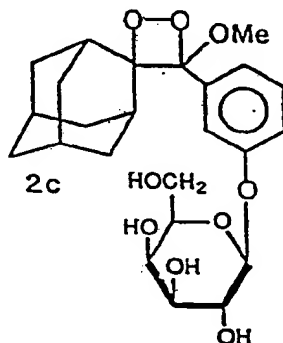
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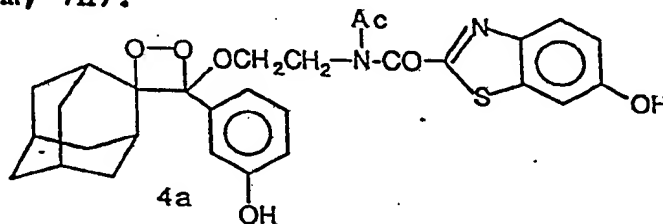
4-(3- $\beta$ -D-Galactopyranosylphenyl)-4-methoxyspiro  
 [1,2-dioxetane-3,2'-adamantane] (2c). Alkene 1c (0.018 g,  
 0.042 mmol) was photooxygenated in 3 mL of dioxane-d<sub>8</sub> at  
 0°C using Sensitox. The reaction was complete after 20 min  
 5 of irradiation using the 1000 W sodium lamp. Spectral data  
 for 2c: <sup>1</sup>H NMR (dioxane-d<sub>8</sub>)  $\delta$  1.593-1.820 (m, 12H), 2.091  
 (s, 1H), 2.517 (s, 1H), 3.160 (s, 3H), 3.670-3.854 (m, 4H),  
 4.147 (d, 1H), 4.422 (d, 1H), 4.846 (d, 1H), 7.078-7.369  
 (m, 4H); <sup>13</sup>C NMR (dioxane-d<sub>8</sub>)  $\delta$  26.209, 26.115, 31.459,  
 10 31.753, 32.890, 33.300, 34.643, 36.332, 49.227, 61.277,  
 68.803, 71.409, 73.856, 75.768, 75.806, 94.558, 101.099,  
 101.331, 111.457, 117.066, 129.246, 136.736, 154.682.

15



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4-(2-(N-Acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)  
 ethoxy)-4-(3-hydroxyphenyl)spiro[1,2-dioxetane-3,2'-  
 adamantane] (4a). Alkene (3a) (25 mg, 0.045 mmol) was  
 photooxygenated in 4 mL of methylene chloride/acetone (1:1)  
 25 at -78°C with a 1000W sodium lamp using 75 mg of Sensitox.  
 TLC analysis (silica gel, 50% ethyl acetate/hexane) showed  
 clean conversion to a more polar material in 90 min.  
 Filtration and removal of solvent gave a white solid as the  
 product (4a): <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  1.56-1.86 (m, 12H), 2.23 (bs,  
 30 1H), 2.36 (s, 3H), 3.11 (bs, 1H), 3.58 - 3.79 (m, 4H),  
 7.15-8.08 (m, 7H).



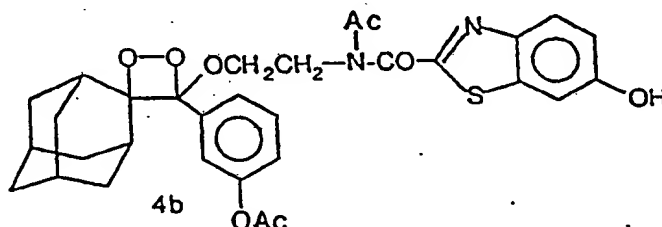
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4-(3-Acetoxyphenyl)-4-(2-(N-acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)ethoxy)spiro[1,2-dioxetane-3,2'-adamantane] 4b

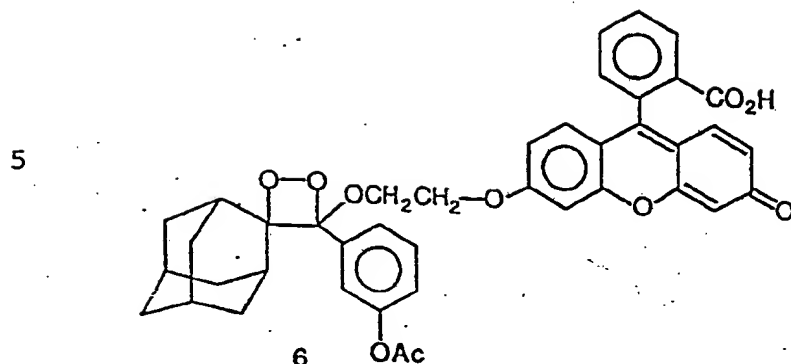
Alkene (3b) (25 mg, 0.042 mmol) was photooxygenated in 4 mL of methylene chloride at -78°C with a 1000W sodium lamp using 75mg of Sensitox. TLC analysis (silica gel, 50% ethyl acetate/hexane) showed clean conversion to a more polar material in 50 min. Filtration and removal of solvent gave the product (4b) as a white solid: <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 1.59-1.86 (m, 12H), 2.16 (bs, 1H), 2.21 (s, 3H), 3.12 (bs, 1H), 3.56-3.80 (m, 4H), 7.09-7.91 (m, 7H); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 20.95, 25.89, 26.05, 31.66, 32.00, 32.23, 32.89, 33.16, 34.85, 36.38, 39.78, 61.43, 95.82, 107.05, 111.46, 117.19, 122.84, 125.19, 129.39, 136.52, 138.86, 147.31, 150.84, 155.96, 160.36, 160.51, 169.24.

20



4-(3-Acetoxyphenyl)-4-(2-(O-fluorescein)ethoxy)spiro[1,2-dioxetane-3,2'-adamantane] (6). [(3-Acetoxyphenyl)(2-(O-fluorescein)ethoxy)methyleneladamantane (5) (35 mg, 0.05 mmol) was dissolved in 1mL of 1,4-dioxane-d<sub>8</sub> in an NMR tube. Sensitox (20 mg) was added and an oxygen bubbler connected. Oxygen was passed slowly through the solution for 5 min and the apparatus immersed in a half-silvered Dewar flask containing ice/water. The sample was irradiated with a 1000 W sodium lamp and a UV cut-off filter while oxygen was bubbled continuously. After 45 min of photooxygenation, <sup>1</sup>H, and <sup>13</sup>C NMR revealed complete conversion of the alkene to its corresponding dioxetane (36.7mg, 0.05 mmol, 100%).

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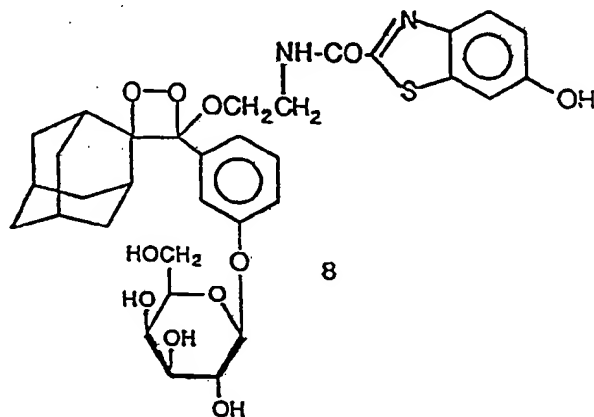


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4-(2-(N-(6-hydroxybenzothiazol-2-yl)amino)ethoxy)-  
4-(3-β-D-galactopyranosylphenyl)spiro[1,2-dioxetane-3,2'-  
adamantane] (8).

Alkene 7 (50mg, 0.075mmol) was photooxygenated in 4 mL of a  
 15 1:1 mixture of methylene chloride and acetone at -78°C with  
 a 1000W high pressure sodium lamp using 100mg of Sensitox.  
 The reaction was stopped after 1hr and filtration and  
 removal of the solvent gave a white solid as the product:  
<sup>1</sup>H NMR δ 1.57-1.9 (m, 12H), 2.2 (s, 1H), 3.08 (s, 1H), 3.37  
 20 (t, 1H), 3.55-3.99 (m, 9H), 4.97 (m, 1H), 6.35 (bs, 4H),  
 3.89-7.9 (m, 8H), 8.41 (bs, 1H), 9.51 (s, 1H); <sup>13</sup>C NMR  
 26.47, 26.66, 32.04, 32.39, 32.50, 33.29, 33.73, 35.07,  
 36.69, 39.97, 61.56, 61.91, 69.44, 71.77, 74.33, 76.09,  
 95.49, 101.83, 102.15, 107.33, 111.88, 117.70, 123.34,  
 25 125.47, 129.86, 137.08, 139.17, 147.46, 157.76, 158.42,  
 160.66, 161.32.

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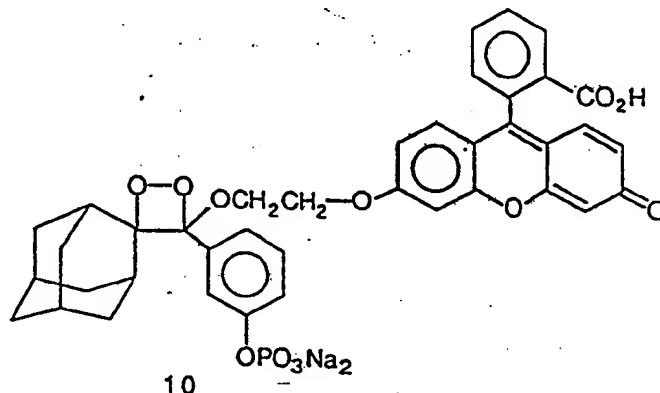
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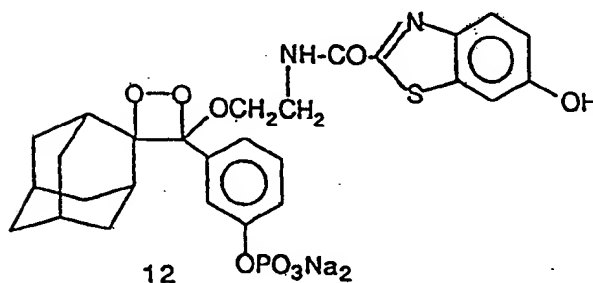
4-(3-Phosphatephenyl)-4-(2-(O-fluorescein)ethoxy)spiro[1,2-dioxetane-3,2'-adamantane] (10) and  
4-(2-(N-(6-hydroxybenzothiazooate-2-carbonyl)amino)ethoxy)-4-(3-phosphatephenyl)spiro[1,2-dioxetane-3,2'-adamantane] (12) are prepared using the photooxygenation procedures described above from alkenes 9 and 11, respectively.

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#### Determination of Chemiluminescence Quantum Yields

The chemiluminescence quantum yield ( $\Phi_{CL}$ ) for the decomposition of dioxetanes is defined as the ratio of einsteins of chemiluminescence emitted to moles of dioxetane decomposed. This quantity is often expressed as an efficiency where chemiluminescence efficiency (%) =  $\Phi_{CL}$ . Sufficient energy is released during the reaction from the reaction enthalpy ( $\Delta H_R$ ) plus the Arrhenius activation energy ( $E_a$ ) to populate the singlet excited state of one of the carbonyl cleavage products. Therefore, the maximum quantum yield is 1.0. Another parameter of interest is the chemiexcitation quantum yield ( $\Phi_{CE}$ ) which is defined as the

-44-

ratio of excited states formed to dioxetane decomposed. The chemiexcitation quantum yield is related to the chemiluminescence quantum yield via the fluorescence quantum yield of the dioxetane cleavage ( $\Phi_F$ ) through the equation:  $\Phi_{CL} = \Phi_{CE} \times \Phi_F$ .

The same procedure as those employed in the measurement of the decay kinetics was used for the determination of chemiluminescence quantum yields with the following modifications. An accurately measured aliquot of a dioxetane stock solution of known concentration was added to 3 mL of the pre-thermostatted organic solvent or aqueous buffer. The reaction was then triggered by adding the appropriate chemical reagent or enzyme. The total light intensity was integrated by a photon-counting luminometer using an RCA A-31034A gallium-arsenide PMT cooled to  $-78^\circ\text{C}$ . Light intensity was converted to photons by reference to a calibration factor based on the accurately known quantum yield of the chemiluminescent reaction of luminol with base in aerated DMSO. The luminol reaction has been determined to have a chemiluminescence quantum yield of 0.011 (1.1%) (J. Lee and H. H. Seliger, Photochem. Photobiol., 15, 227 (1972); P. R. Michael and L. R. Faulkner, Anal. Chem., 48, 1188 (1976)).

#### Acquisition of Chemiluminescence Spectra

Spectra of the chemiluminescence from chemically or enzymatically triggered dioxetanes were obtained by conducting the reaction in a 1-cm square quartz cuvette in the sample compartment of a Spex Fluorolog spectrofluorometer at ambient temperature. Correction for the decay of the chemiluminescence intensity during the wavelength scan was made by accumulating the spectrum in a ratio mode so that the observed spectrum was divided by the signal from an auxiliary detector (EMI 9781B) which measures the total signal as a function of time. The monochromator bandpass was typically 18 nm. For weakly emitting samples, several identical scans were performed and added together to improve the signal-to-noise ratio.

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## Triggering of Dioxetanes

1. Chemical Triggering of the Chemiluminescence of Hydroxy-Substituted Dioxetane 2a and Acetoxy-Substituted Dioxetane 2b in DMSO and Aqueous Solution. Treatment of 5  $10^{-4}$  M solutions of dioxetanes 2a and 2b in DMSO at room temperature ( $25^{\circ}\text{C}$ ) with an excess of tetra-n-butylammonium hydroxide or tetra-n-butylammonium fluoride resulted in intense blue chemiluminescence which decayed over several minutes. The emission maximum for the chemiluminescence is 10 470 nm. The fluorescence of the anion of the cleavage product (methyl 3-hydroxybenzoate, MHB) is identical to the chemiluminescence spectrum. These results demonstrate that the chemiluminescence process involves: (a) base triggering to yield the unstable aryloxide form of the dioxetane, (b) 15 subsequent cleavage of this species to generate MHB in the singlet excited states, and (c) fluorescence of MHB to yield the luminescence with an overall efficiency which can be as high as 25%. These results are comparable to those previous reported for fluoride-triggered chemiluminescence 20 of the corresponding silyloxy-substituted dioxetane (A. P. Schaap, patent application filed 7/15/86; A. P. Schaap, T. S. Chen, R. S. Handley, R. DeSilva, and B. P. Giri, Tetrahedron Lett., 1155 (1987)).

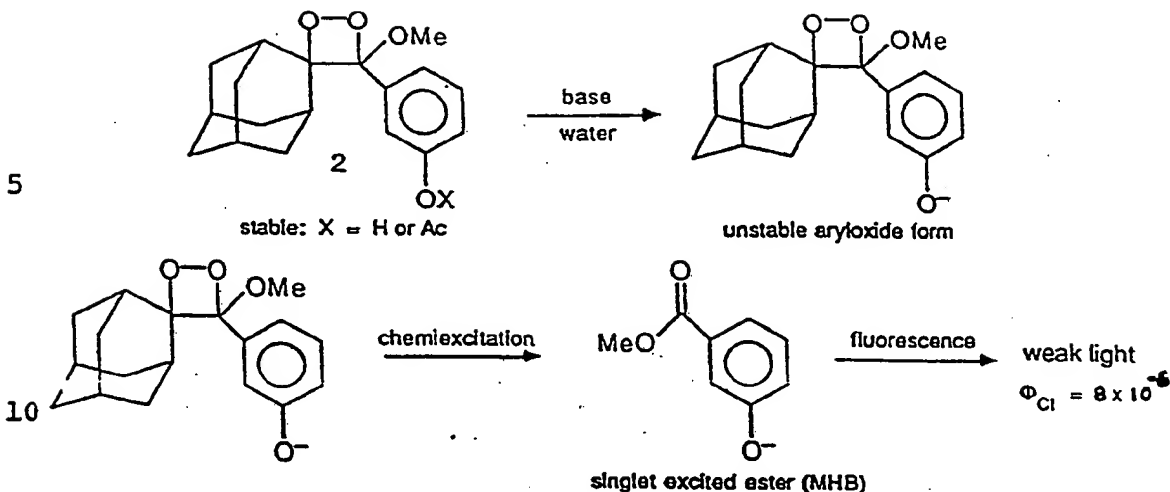
In contrast, chemical triggering of 2a and 2b in 25 aqueous solution with various bases including NaOH results in extremely low levels of luminescence (0.0008% chemiluminescence efficiency). This low value results from the fact that the ester MHB is essentially non-fluorescent in the aqueous environment.

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## 2. Chemical Triggering of the Chemiluminescence of Dioxetanes 4 and 6: Enhanced Chemiluminescence

### Efficiency via Intramolecular Energy Transfer to a Tethered

15 Fluorescer. It has now been discovered that chemiluminescence efficiencies from triggerable dioxetanes can be dramatically enhanced through intramolecular energy transfer to a fluorescent group that is chemically attached or tethered to the excited cleavage product of the

20 dioxetane. In these new compounds, the aryloxy-substituted dioxetane is utilized for the "energy-generating" function and the "light-emitting" process is carried out by an efficiently fluorescent group that is tethered to the excited cleavage product.

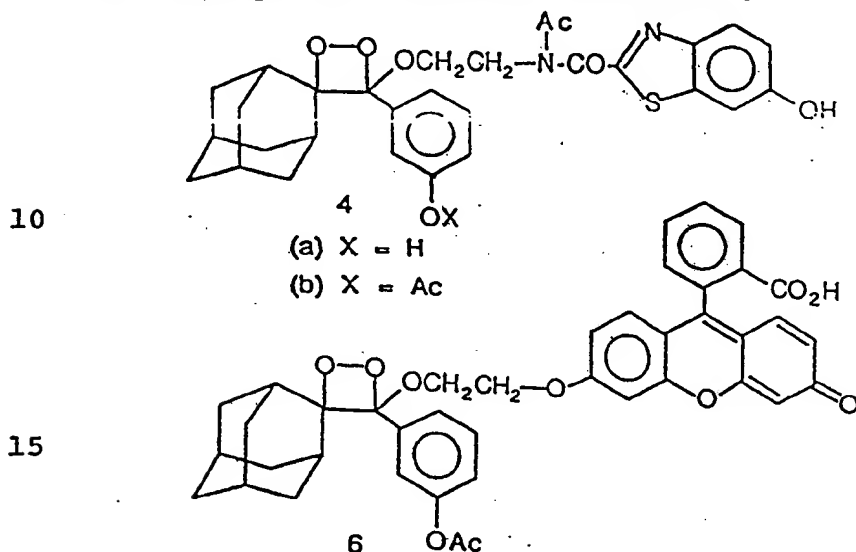
25 Normally, with dioxetanes such as 2a and 2b (shown above), removal of the protecting group X by a chemical reagent or an enzyme produces the unstable form of the dioxetane which cleaves to generate the singlet excited ester. Emission from this species provides direct

30 chemiluminescence. However, in the presence of a lower energy fluorescer that is tethered to the excited product through a series of connecting atoms such as in dioxetanes 4 and 6, intramolecular energy transfer can yield the excited state of the fluorescer (for example, see Scheme 1).

35 Emission from this moiety affords energy-transfer chemiluminescence. With favorable energetics for energy transfer and an optimum number of atoms for the length of the tether, the efficiency of energy-transfer ( $\Phi_{ET}$ ) can

-47-

approach unity. Further, if the fluorester is selected to have a higher  $\Phi_F$  than the energy donor, the overall chemiluminescence can be enhanced. Additionally, the color of the luminescence can be selected from blue to red with the appropriate tethered fluorester.



Chemical triggering experiments with dioxetanes 4 and 6 illustrate the large increases in chemiluminescence efficiencies that can be achieved by with these novel dioxetanes (see Table 1). For example, the fluoride-triggered reaction in DMSO of dioxetane 4b gives an intense blue-green emission with an efficiency of 49%, double the efficiency of dioxetane 2b under the same conditions. Similar results are obtained with base and fluoride triggering of the hydroxy-substituted dioxetane 4a. Even larger enhancements are observed for reactions conducted in aqueous solutions with increases for tethered dioxetanes 4 and 6 of up to 450-fold, compared to 2a and 2b (Table 1). As shown by the spectra in Figures 1, 3 and 4, the normal emission at 470 nm is quenched and replaced by the emission of the tethered fluorester, demonstrating the very high efficiency for intramolecular energy transfer in these novel compounds. These figures also illustrate the enhancement in chemiluminescence efficiency that is achieved in both the chemical and enzymatic triggering of the dioxetanes bearing tethered fluoresters.

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Table 1. Chemiluminescence Efficiencies (%) for  
Acetoxy-Substituted Dioxetanes

Triggering Conditions		Dioxetane 2b	Dioxetane 4b	Dioxetane 6
5	Enzymatic: aryl esterase, pH 9.2	0.0012	0.29	0.39
	Chemical: aqueous NaOH	0.00084	0.20	0.38
	Chemical: aqueous CTAB, NaOH	0.017	2.2	1.4
10	Chemical: DMSO, fluoride	25	49	-

3. Enzymatic Triggering of the Chemiluminescence of Dioxetanes 4b and 6: Enhanced Chemiluminescence Efficiency via Intramolecular Energy Transfer to a Tethered Fluorescer. Aryl esterase (carboxyl esterase) from porcine liver was obtained from Sigma Chemical Co. as a suspension in 3.2 M  $(\text{NH}_4)_2\text{SO}_4$ . In a typical experiment, 50  $\mu\text{L}$  of a  $2.56 \times 10^{-3}$  M stock solution of the dioxetane in 221 buffer was added to 3 mL of 221 buffer (0.75 M, pH 9.2) giving a final dioxetane concentration of  $4.3 \times 10^{-5}$  M. Injection of a 10  $\mu\text{L}$  aliquot of diluted enzyme into the solution at 37°C resulted in chemiluminescence. The chemiluminescence efficiencies for enzymatic triggering of tethered dioxetanes 4b and 6 were found to be 0.29 and 0.39% respectively. These values represent enhancements of 240- and 325-fold, respectively, compared to the direct luminescence obtained from the reaction of dioxetane 2b under the same conditions.

The chemiluminescence spectra in Figure 4 show the normal weak emission (Curve A,  $\lambda = 470\text{nm}$ ) for 2b and the energy-transfer chemiluminescence (Curve B,  $\lambda = 519\text{ nm}$ ) derived from 4b with aryl esterase. A comparison of the chemiluminescence spectrum of the enzymatic triggering of dioxetane 4b with the fluorescence spectrum of the cleavage

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product under the same conditions demonstrates that the emission does, in fact, arise from the tethered fluorescer (Figure 5). The kinetics of the reactions with 4b and 6 indicates that the tethered fluoroscres do not

- 5 significantly inhibit the enzymatic turn-over of the substrate. Further, the enzyme does not seem to interfere with intramolecular energy transfer.

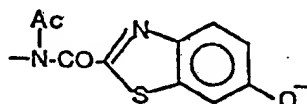
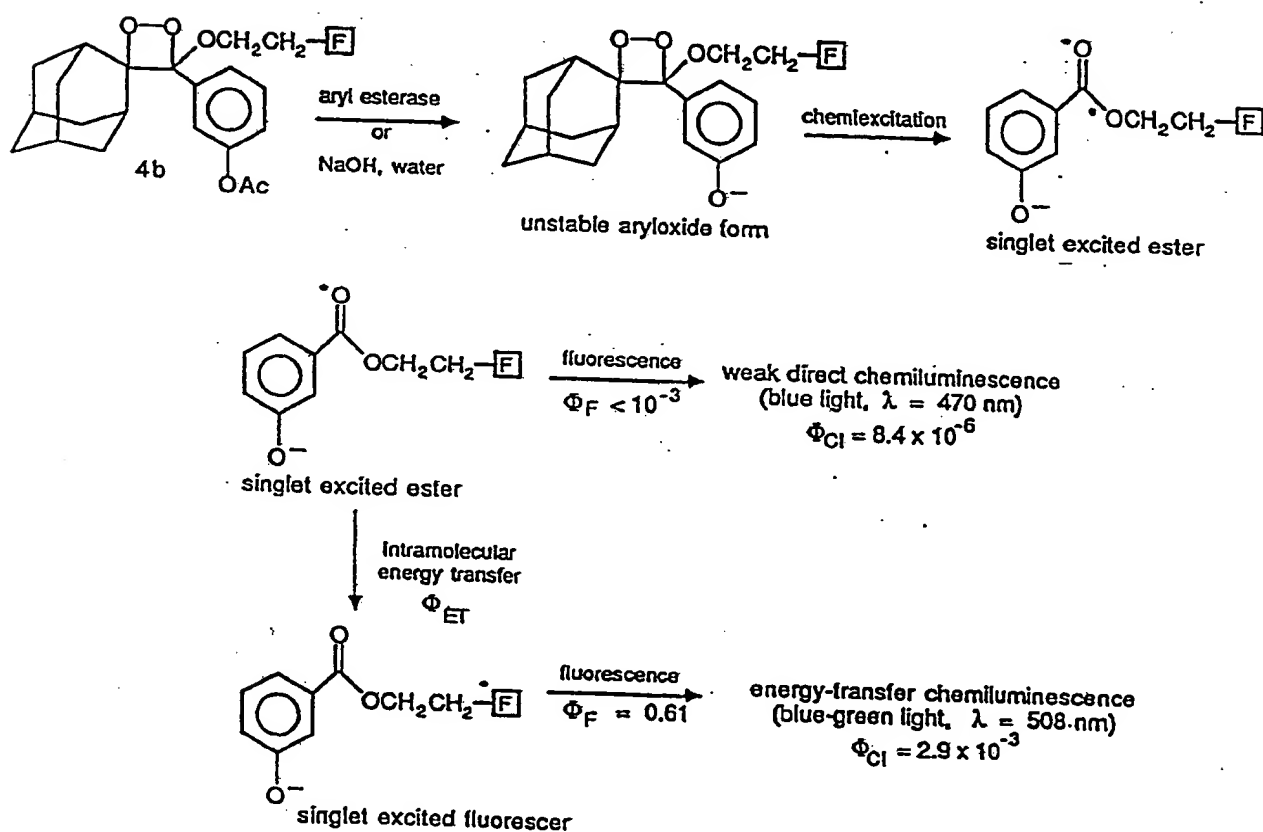
4. Enzymatic Triggering of the  
Chemiluminescence of Dioxetane 8: Enhanced  
10 Chemiluminescence Efficiency via Intramolecular Energy  
Transfer to a Tethered Fluorescer.  $\beta$ -Galactosidase (Sigma) was reacted with solutions of the galactopyranosyl-substituted dioxetanes 2c and 8. In a typical experiment, 100  $\mu$ L of enzyme solution was added to  
15 3mL of dioxetane solution (0.0028 mmol) in phosphate buffer (pH 7.2) at 37°C. The solutions were incubated for 5 min after which time NaOH was added to increase the pH of the solutions to trigger the luminescence of the deprotected dioxetane (the hydroxy form). The chemiluminescence  
20 intensity with dioxetane 8 was enhanced by over 200-fold compared to dioxetane 2c. These results further illustrate the significant increases in light yields that can be obtained through the use of intramolecular energy transfer to tethered fluoroscres.

- 25 A comparison of the chemiluminescence spectrum of the enzymatic triggering of dioxetane 8 with the fluorescence spectrum of the cleavage product under the same conditions demonstrates again that the emission does, in fact, arise from the tethered fluorescer (Figure 9).

- 30 Similar spectroscopic results are obtained with the phosphate-substituted dioxetanes 10 and 12 with enhanced chemiluminescence intensities compared to dioxetane 2d.

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**SCHEME 1: MECHANISM OF CHEMICAL- AND ENZYME-TRIGGERED ENERGY-TRANSFER CHEMILUMINESCENCE IN AQUEOUS SOLUTION**



—[F] = tethered fluorescer

Under the conditions of the reactions,  
the fluorescer exists in the ionized form.

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In addition to the specific alkenes and dioxetanes bearing OX groups on the aryl ring in the meta position described herein, the corresponding para and ortho isomers can be prepared by similar procedures. Such

5 compounds are for example for the dioxetanes:

Dioxetanes

- 4-(4-Hydroxyphenyl)-4-methoxyspiro[1,2-dioxetane-3,2'-adamantane]
- 4-(4-Acetoxyphenyl)-4-methoxyspiro[1,2-dioxetane-3,2'-adamantane]
- 10 4-(4-Phosphatephenyl)-4-methoxyspiro[1,2-dioxetane-3,2'-adamantane], salt
- 4-(4- $\beta$ -D-Galactopyranosylphenyl)-4-methoxyspiro[1,2-dioxetane-3,2'-adamantane]
- 15 4-(2-(N-Acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)ethoxy)-4-(4-hydroxyphenyl)spiro[1,2-dioxetane-3,2'-adamantane]
- 4-(4-Acetoxyphenyl)-4-(2-(N-acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)ethoxy)spiro[1,2-dioxetane-3,2'-adamantane]
- 20 4-(4-Acetoxyphenyl)-4-(2-(O-fluorescein)ethoxy)spiro[1,2-dioxetane-3,2'-adamantane]
- 4-(2-(N-(6-Hydroxybenzothiazole-2-carbonyl)amino)ethoxy)-4-(4- $\beta$ -D-galactopyranosylphenyl)spiro[1,2-dioxetane-3,2'-adamantane]
- 25 4-(4-Phosphatephenyl)-4-(2-(O-fluorescein)ethoxy)spiro[1,2-dioxetane-3,2'-adamantane], salt
- 4-(2-(N-(6-Hydroxybenzothiazole-2-carbonyl)amino)ethoxy)-4-(4-phosphatephenyl)spiro[1,2-dioxetane-3,2'-adamantane],
- 30 salt

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-52-

for the alkenes:

[(4-Hydroxyphenyl)methoxymethylene]adamantane

[(4-Acetoxyphenyl)methoxymethylene]adamantane

[(4-Phosphatephenyl)methoxymethylene]adamantane, salt

5 [(4-( $\beta$ -D-Galactopyranosyl)phenyl)methoxymethylene]

adamantane

{[2-(N-(6-tert-Butyldimethylsilyloxybenzothiazole-2-carbonyl)amino)ethoxy][4-hydroxyphenyl]methylene}adamantane

{[2-(N-Acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)

10 ethoxy][4-hydroxyphenyl]methylene}adamantane

{[4-Acetoxyphenyl][2-(N-acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)ethoxy]methylene}adamantane

[(4-Acetoxyphenyl)(2-(O-fluorescein)ethoxy)methylene]  
adamantane

15 {[2-(N-(6-Hydroxybenzothiazole-2-carbonyl)amino)ethoxy][4- $\beta$ -D-galactopyranosylphenyl]methylene}adamantane

[(4-Phosphatephenyl)(2-(O-fluorescein)ethoxy)methylene]  
adamantane, salt

{[2-(N-(6-Hydroxybenzothiazole-2-carbonyl)amino)ethoxy][4-

20 phosphatephenyl]methylene}adamantane, salt

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In addition to the specific examples described herein, a wide variety of standard literature methods can be employed for the coupling of fluorescers to the alkene or the dioxetane. These reactions include but are not  
5 limited to: nucleophilic displacements, electrophilic substitutions, additions to alkenes and carbonyl compounds, nucleophilic addition to carboxylic acid derivatives, and additions to isothiocyanates and isocyanates.

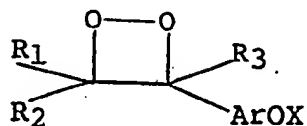
It is intended that the foregoing description be  
10 only illustrative of the present invention and that the invention be limited only by the hereinafter appended claims.

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## I CLAIM:

-1-

A dioxetane compound of the formula:



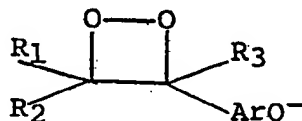
(I)

wherein  $R_1$ ,  $R_2$  and  $R_3$  are carbon containing groups and optionally containing oxygen, nitrogen or sulfur which allow the production of the light,

wherein one of  $R_1$ ,  $R_2$  and  $R_3$  is a tethered fluorescent molecule containing group wherein the fluorescent molecule exhibits fluorescence between, approximately 400 and 900 nanometers,

wherein  $R_1$  and  $R_2$  can be joined together,  
wherein  $R_3$  and ArOX can be joined together,

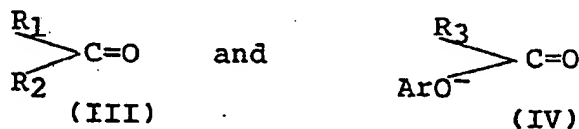
wherein X is a leaving group,  
wherein compound (I) decomposes to form an aryl oxide (II) of the formula



(II)

when reacted with an activating agent which removes X,

wherein the aryl oxide (II) spontaneously decomposes to form compounds (III) and (IV) of the formulae:



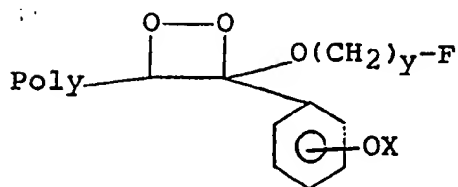
(III)

(IV)

and wherein the fluorescent molecule in the fluorescent molecule containing group is activated to produce light upon the decomposition of the aryl oxide.

-55-  
-2-

A dioxetane compound of the formula:



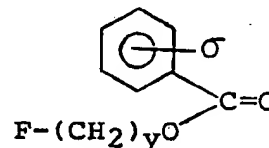
wherein Poly is a spirofused polycyclic alkylene group containing 6 to 30 carbon atoms and optionally oxygen and nitrogen,

wherein F is a fluorescent molecule containing group wherein the fluorescent molecule exhibits fluorescence between 400 and 900 nanometers,

wherein y is an integer between 1 and 14, and

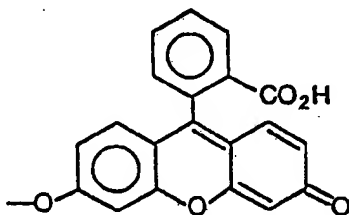
wherein X is a leaving group which when removed by an activating agent produces an oxide intermediate of the dioxetane compound which spontaneously decomposes to form light because of F and carbonyl containing molecules of the formulae

Poly=O and



-3-

The compound of Claim 2 wherein F is fluorescein of the formula:

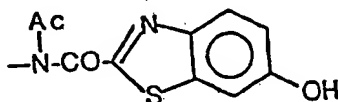


-56-

- 4 -

The compound of Claim 2 wherein F is a benzothiazole of the formula:

5

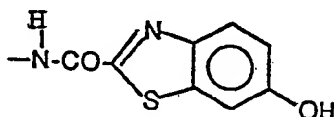


10 wherein Ac is acetyl.

-5-

The compound of Claim 2 wherein F is a benzothiazole of the formula:

5



-6-

The compound of Claim 2 wherein X is selected from the group consisting of hydroxyl, alkyl or aryl carboxyl ester, inorganic oxyacid salt, alkyl or aryl silyloxy and oxygen pyranoside.

-7-

The compound of Claim 2 wherein F is selected from the group consisting of fluorescent dyes, aromatic compounds including benzene derivatives, naphthalene derivatives, anthracene derivatives, pyrenes, biphenyls, acridines, coumarins, xanthenes, phthalocyanines, stilbenes, furans, oxazoles, oxadiazoles, benzothiazoles, fluoresceins, rhodamines, eosins, resorufins, quinolines.

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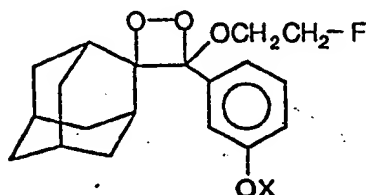
- 8 -

The compound of Claim 2 wherein Poly is an adamantyl group.

-9-

A compound of the formula:

5



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wherein X is a leaving group and F is N-acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino or N-(6-hydroxybenzothiazole-2-carbonyl)amino.

-10-

The compound of Claim 9 wherein X is hydrogen.

-11-

The compound of Claim 9 wherein X is an acetyl group.

-12-

The compound of Claim 8 wherein X is a galactopyranosyl group.

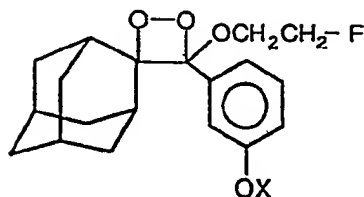
-13-

The compound of Claim 9 wherein X is a phosphate group.

-58-  
-14-

A compound of the formula:

5



10 wherein X is a leaving group and F is O-fluorescein.

-15-

The compound of Claim 14 wherein X is hydrogen.

-16-

The compound of Claim 14 wherein X is an acetyl group.

-17-

The compound of Claim 15 wherein X is a galactopyranosyl group.

-18-

The compound of Claim 15 wherein X is a phosphate group.

-19-

[(3-( $\beta$ -D-Galactopyranosyl)phenyl) methoxymethylene]adamantane.

-20-

[(3-tert-Butyldimethylsilyloxyphenyl) (2-chloroethyl)methylene]adamantane.

-21-

[(2-Chloroethoxy)(3-hydroxyphenyl) methylene]adamantane.

-59-  
-22-

[(3-Hydroxyphenyl)(2-iodoethoxy)  
methylene]adamantane.

-23-

[(2-Aminoethoxy)(3-hydroxyphenyl)  
methylene]adamantane.

-24-

{[2-(N-(6-tert-Butyldimethylsilyloxy-  
benzothiazole-2-carbonyl)amino)ethoxy][3-hydroxyphenyl]methy-  
lene}adamantane.

-25-

{[2-(N-Acetyl-N-(6-hydroxybenzothiazole-2-  
carbonyl)amino)ethoxy][3-hydroxyphenyl]methylene}adamantane.

-26-

{[3-Acetoxyphenyl][2-(N-acetyl-N-(6-hydroxybenzo-  
thiazole-2-carbonyl)amino)ethoxy]methylene}adamantane.

-27-

[(3-Acetoxyphenyl)(2-(O-fluorescein)ethoxy)  
methylene]adamantane.

-28-

[(2-Aminoethoxy)(3- $\beta$ -  
-D-galactopyranosylphenyl)methylene]adamantane.

-29-

{[2-(N-(6-Hydroxybenzothiazate-2-carbonyl)  
amino)ethoxy][3- $\beta$ -D-galactopyranosylphenyl]methylene}  
adamantane.

-30-

[(3-Phosphatephenyl)(2-(O-fluorescein)ethoxy)  
methylene]adamantane.

-60-  
-31-

{[2-(N-(6-Hydroxybenzothiazate-2-carbonyl) amino)ethoxy][3-phosphatephenyl]methylene}adamantane, disodium salt.

-32-

4-(3-β-D-Galactopyranosylphenyl)-4-methoxyspiro [1,2-dioxetane-3,2'-adamantane].

-33-

4-(2-(N-Acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)ethoxy)-4-(3-hydroxyphenyl)spiro[1,2-dioxetane-3,2'-adamantane].

-34-

4-(3-Acetoxyphenyl)-4-(2-(N-acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino)ethoxy)spiro[1,2-dioxetane-3,2'-adamantane].

-35-

4-(3-Acetoxyphenyl)-4-(2-(O-fuorescein)ethoxy) spiro[1,2-dioxetane-3,2'-adamantane].

-36-

4-(2-(N-(6-Hydroxybenzothiazate-2-carbonyl) amino) ethoxy)-4-(3-β-D-galactopyran o sylphenyl)spiro[1,2-dioxetane-3,2'-adamantane].

-37-

4-(3-Phosphatephenyl)-4-(2-(O-fuorescein) ethoxy)spiro[1,2-dioxetane-3,2'-adamantane].

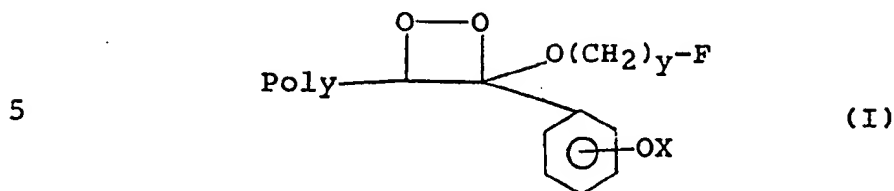
-38-

4-(2-(N-(6-Hydroxybenzothiazate-2-carbonyl) amino)ethoxy)-4-(3-phosphatephenyl)spiro[1,2dioxetane-3,2'-a damantane].

-61-

-39-

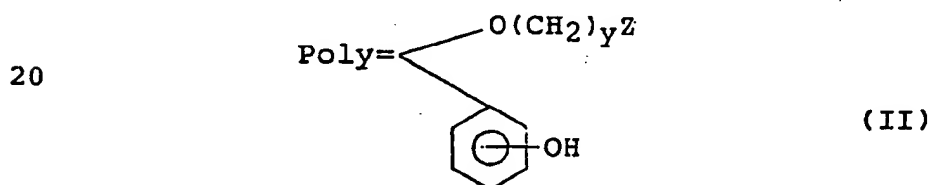
In a process for preparing a dioxetane compound (I) of the formula:



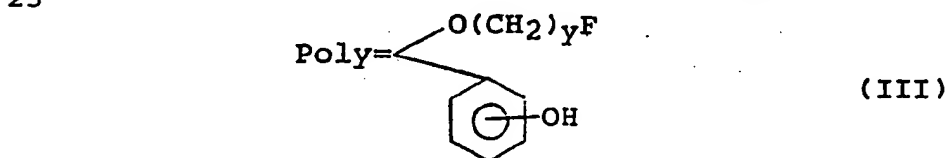
wherein Poly is a spirofused polycyclic alkylene group,  
 10 wherein y is an integer between 1 and 14 and wherein F is a fluorescent molecule group,

wherein X is a leaving group, which when removed by an activating agent produces an oxide intermediate of the dioxetane compound which spontaneously decomposes to  
 15 form light because of F, which comprises:

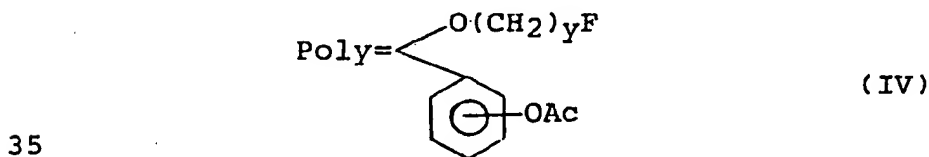
(a) reacting in an organic solvent, a compound (II) of the formula:



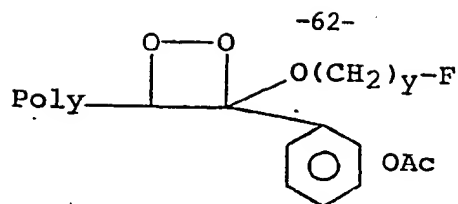
wherein Z is a reactive group, with FA wherein A is reactive with Z to form a compound (III) of the formula:



30 (b) reacting the compound (III) with acetyl chloride to form the compound (IV) of the formula:



(c) reacting oxygen with compound (IV) to form a dioxetane compound of the formula:



, wherein Ac is acetyl.

-40-

The process of Claim 39 wherein Z is an amine group and A is a carbonyl group which are reacted to produced a carbonyl amino group.

-41-

The process of Claim 39 wherein Y is 2, wherein Z is an iodo group wherein FA is fluorescein.

-42-

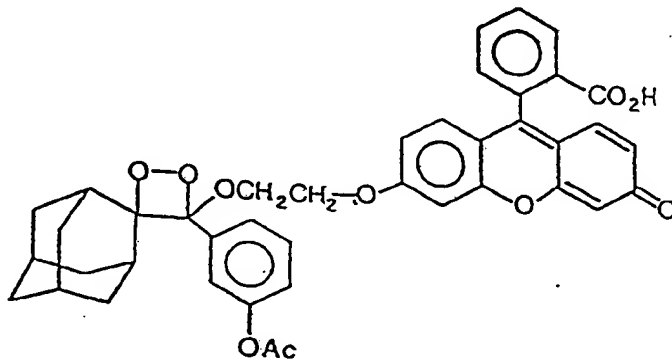
The process of Claim 39 wherein Y is 2, wherein Z is an amino group, FA is 6-tert-butyldimethylsilyloxy-2-benzothiazoate.

-43-

The process of Claim 39 wherein the organic solvent is benzene.

-44-

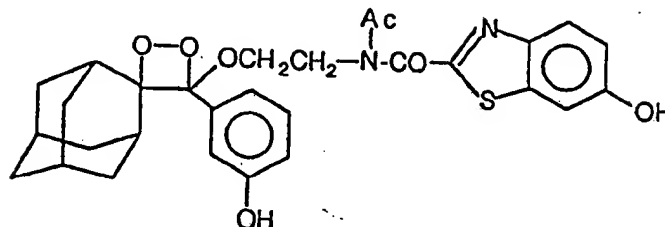
The process of Claim 39 wherein the dioxetane compound has the formula:



-63-

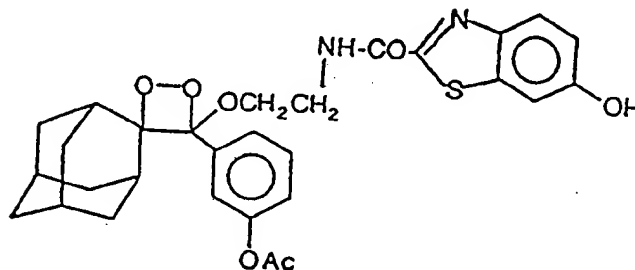
-45-

The process of Claim 39 wherein the dioxetane compound has the formula:



-46-

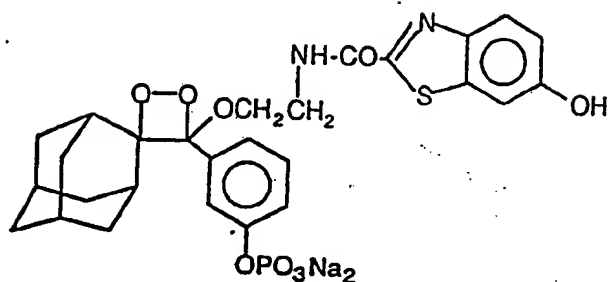
The process of Claim 39 wherein the dioxetane compound has the formula:





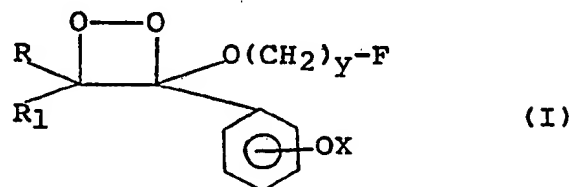
-65-  
-49-

The process of Claim 39 wherein the dioxetane has the formula:



-50-

In a process for preparing a dioxetane compound (I) of the formula:



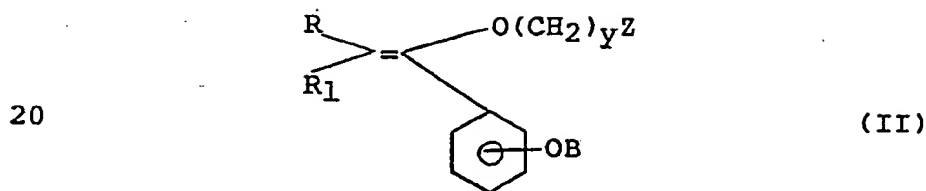
wherein R and R<sub>1</sub> and groups which allow the production of light and can be joined together, wherein y is an integer between 1 and 14 and wherein F is a fluorescent molecule group,

wherein X is a leaving group, which when removed by an activating agent produces an oxide intermediate of the dioxetane compound which spontaneously decomposes to form light because of F, which comprises:

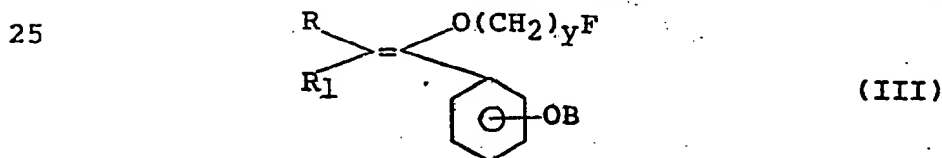
(a) reacting in an organic solvent, a compound

-66-

(II) of the formula:

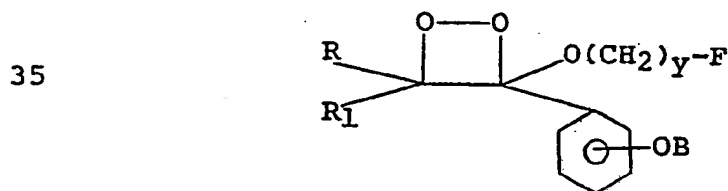


wherein Z is a reactive group, with FA wherein A is reactive with Z to form a compound (III) of the formula:



30 wherein B is a non photo-oxidatively reactive group selected from the group consisting of X or groups which can be converted to X; and

(b) reacting oxygen with compound (III) to form a dioxetane compound of the formula:



-51-

The process of Claim 50 wherein Z is an amine group and A is a carbonyl group which are reacted to produce a carbonyl amino group.

-52-

The process of Claim 50 wherein Y is 2, wherein Z is an iodo group wherein FA is fluorescein and X is selected from the group consisting of an acetyl group and hydrogen.

-67-  
-53-

The process of Claim 50 wherein Y is 2, wherein Z is an amino group, FA is 6-tert-butyldimethylsilyloxy-2-benzothiazoate and X is selected from the group consisting of acetyl group and hydrogen.

-54-

The process of Claim 50 wherein the organic solvent is benzene.

-55-

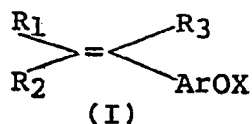
The process of Claim 50 wherein B is beta-galactopyranosyl.

-56-

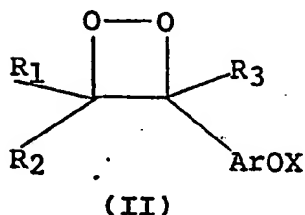
The process of Claim 50 wherein B is a phosphate group.

-68-  
-57-

An alkene of the formula:



which can be oxidized to a dioxetane compound of the  
5 formula:



wherein R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> are carbon containing  
groups and optionally containing oxygen, nitrogen or sulfur  
which allow the production of the light,

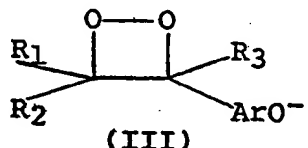
wherein one of R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> is a tethered  
15 fluorescent molecule containing group wherein the  
fluorescent molecules exhibit fluorescence between  
approximately 400 and 900 nanometers,

wherein R<sub>1</sub> and R<sub>2</sub> can be joined together,

wherein R<sub>3</sub> and ArOX can be joined together,

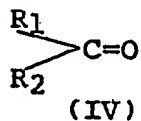
wherein X is a leaving group,

wherein compound (II) decomposes to form an aryl  
oxide (III) of the formula

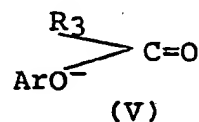


when reacted with an activating agent which removes X,

wherein the aryl oxide (III) spontaneously  
decomposes to form compounds (IV) and (V) of the formulae:



and

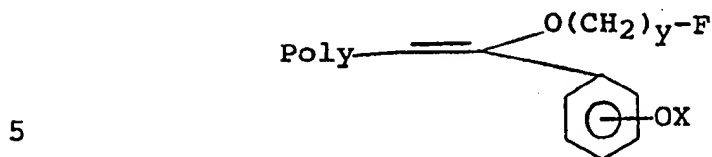


and wherein the fluorescent molecule in the fluorescent  
molecule containing group is activated to produce light  
upon the decomposition of the aryl oxide.

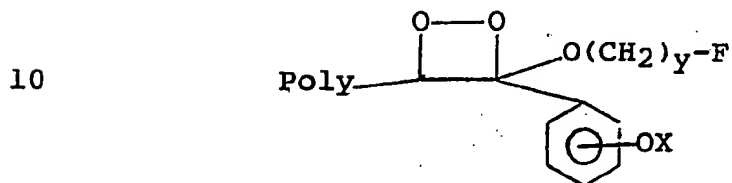
-69-

-58-

An alkene of the formula:



which can be oxidized to a dioxetane compound of the formula:



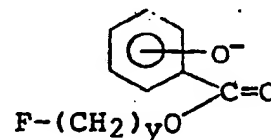
15 wherein Poly is a spirofused polycyclic alkylene group containing 6 to 30 carbon atoms and optionally oxygen and nitrogen,

wherein F is a fluorescent molecule containing group wherein the fluorescent molecule exhibits fluorescence between 400 and 900 nanometers,

20 wherein y is an integer between 1 and 14, and

wherein X is a leaving group which when removed by an activating agent produces an oxide intermediate of the dioxetane compound which spontaneously decomposes to form light because of F and carbonyl containing molecules of the formulae

Poly=O and

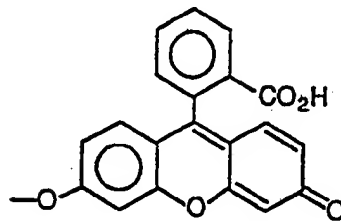


30

-70-

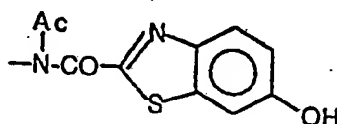
-59-

The compound of Claim 58 wherein F is fluorescein of the formula:



-60-

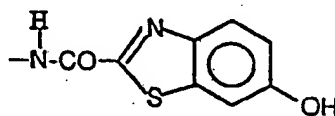
The compound of Claim 58 wherein F is a benzothiazole of the formula:



wherein Ac is acetyl.

-61-

The compound of Claim 58 wherein F is a benzothiazole of the formula:



-62-

The compound of Claim 58 wherein X is selected from the group consisting of hydroxyl, alkyl or aryl carboxyl ester, inorganic oxyacid salt, alkyl or aryl silyloxy and oxygen pyranoside.

-71-

-63-

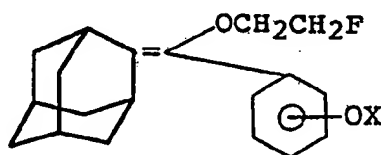
The compound of Claim 58 wherein F is selected from the group consisting of fluorescent dyes, aromatic compounds including benzene derivatives, naphthalene derivatives, anthracene derivatives, pyrenes, biphenyls, acridines, coumarins, xanthenes, phthalocyanines, stilbenes, furans, oxazoles, oxadiazoles, benzothiazoles, fluoresceins, rhodamines, eosins, resorufins, quinolines.

-64-

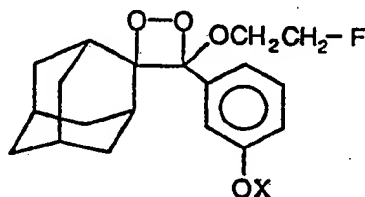
The compound of Claim 58 wherein Poly is an adamantyl group.

-65-

An alkene of the formula:



which can be oxidized to a dioxetane compound of the formula:



wherein X is a leaving group and F is N-acetyl-N-(6-hydroxybenzothiazole-2-carbonyl)amino or N-(6-hydroxybenzothiazole-2-carbonyl)amino.

-66-

The compound of Claim 65 wherein X is hydrogen.

-67-

The compound of Claim 65 wherein X is an acetyl group.

-72-  
-68-

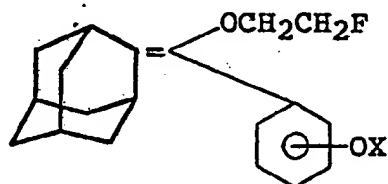
The compound of Claim 65 wherein X is a galactopyranosyl group.

-69-

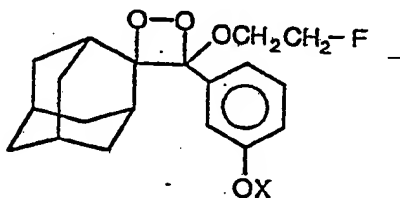
The compound of Claim 65 wherein X is a phosphate group.

-70-

An alkene of the formula:



which can be oxidized to a compound of the formula:



wherein X is a leaving group and F is O-fluorescein.

-71-

The compound of Claim 70 wherein X is hydrogen.

-72-

The compound of Claim 70 wherein X is an acetyl group.

-73-

The compound of Claim 70 wherein X is a galactopyranosyl group.

-74-

The compound of Claim 70 wherein X is a phosphate group.

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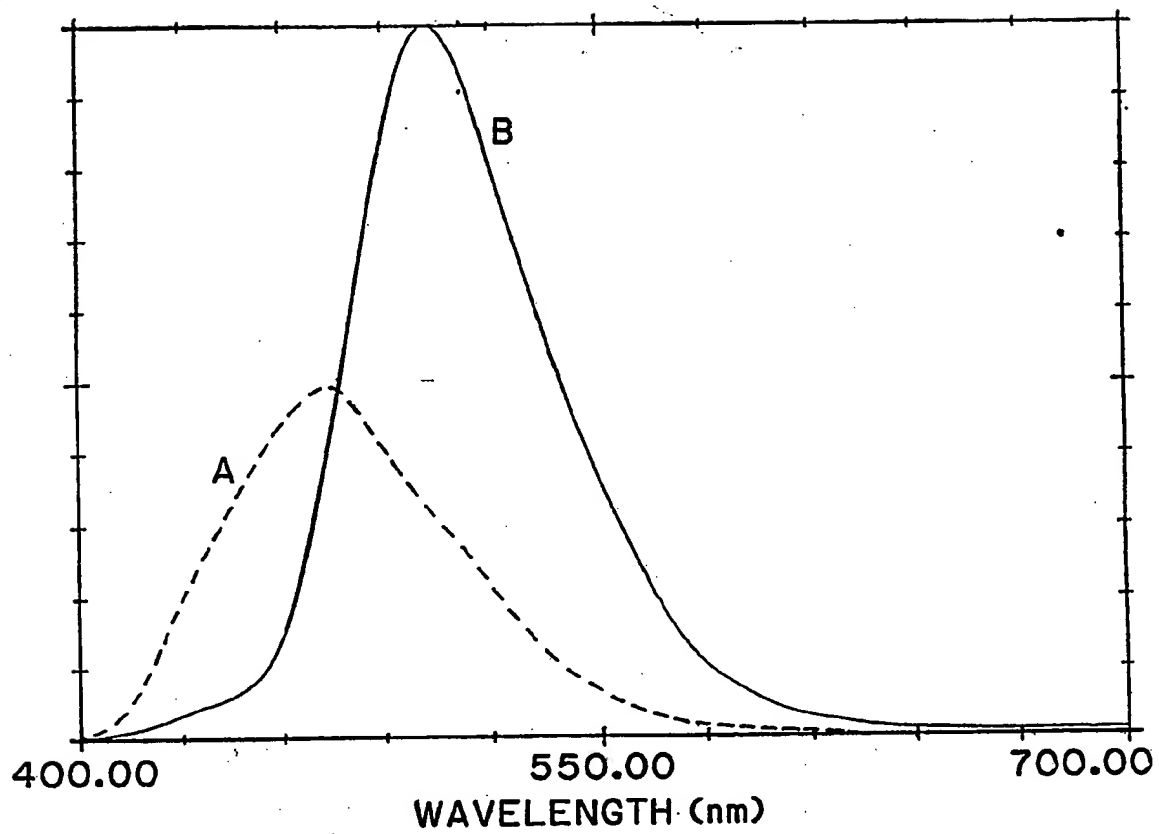


FIG. 1

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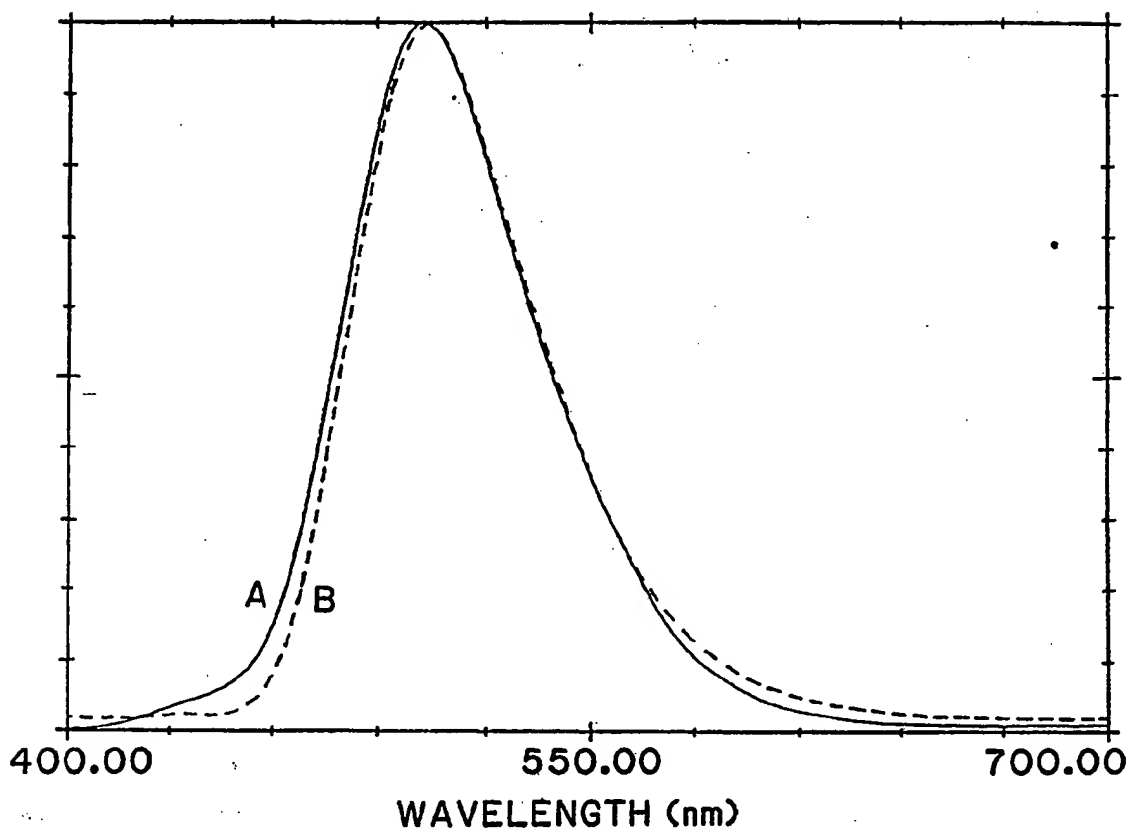


FIG. 2

SUBSTITUTE SHEET

3/6

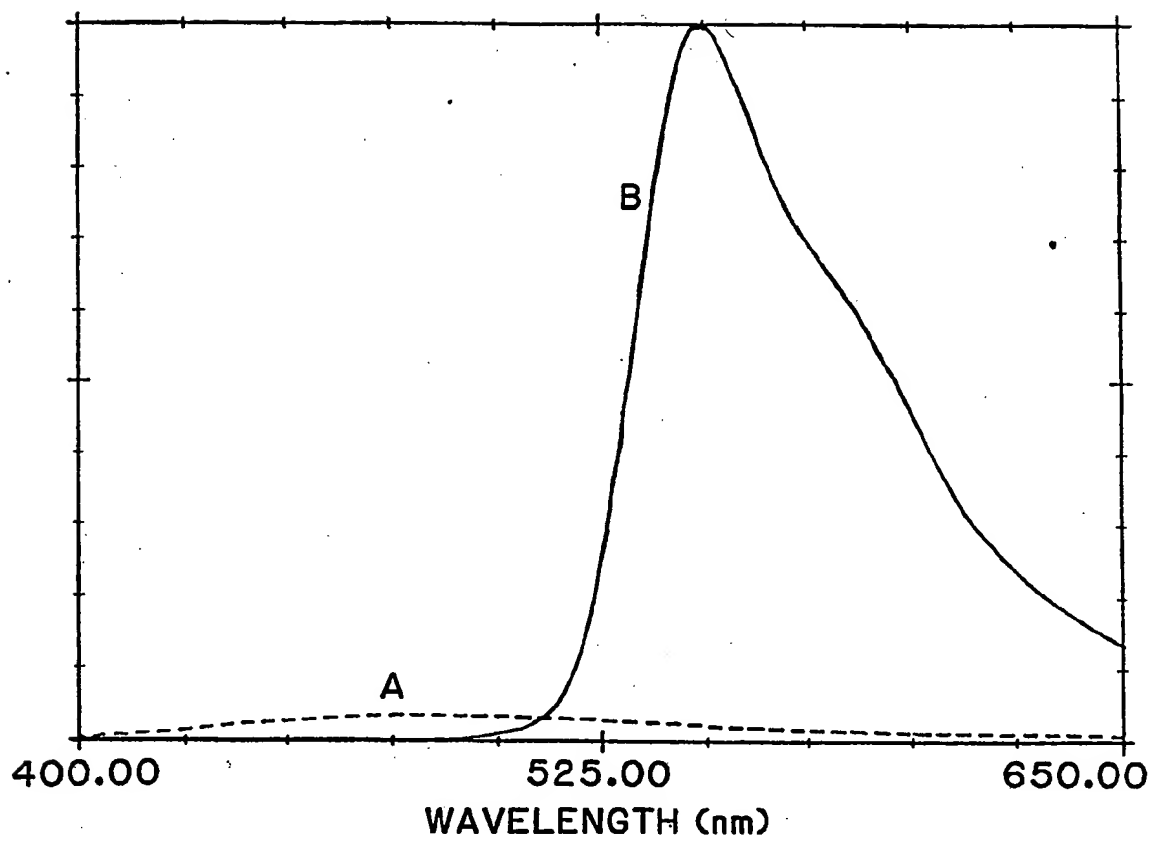
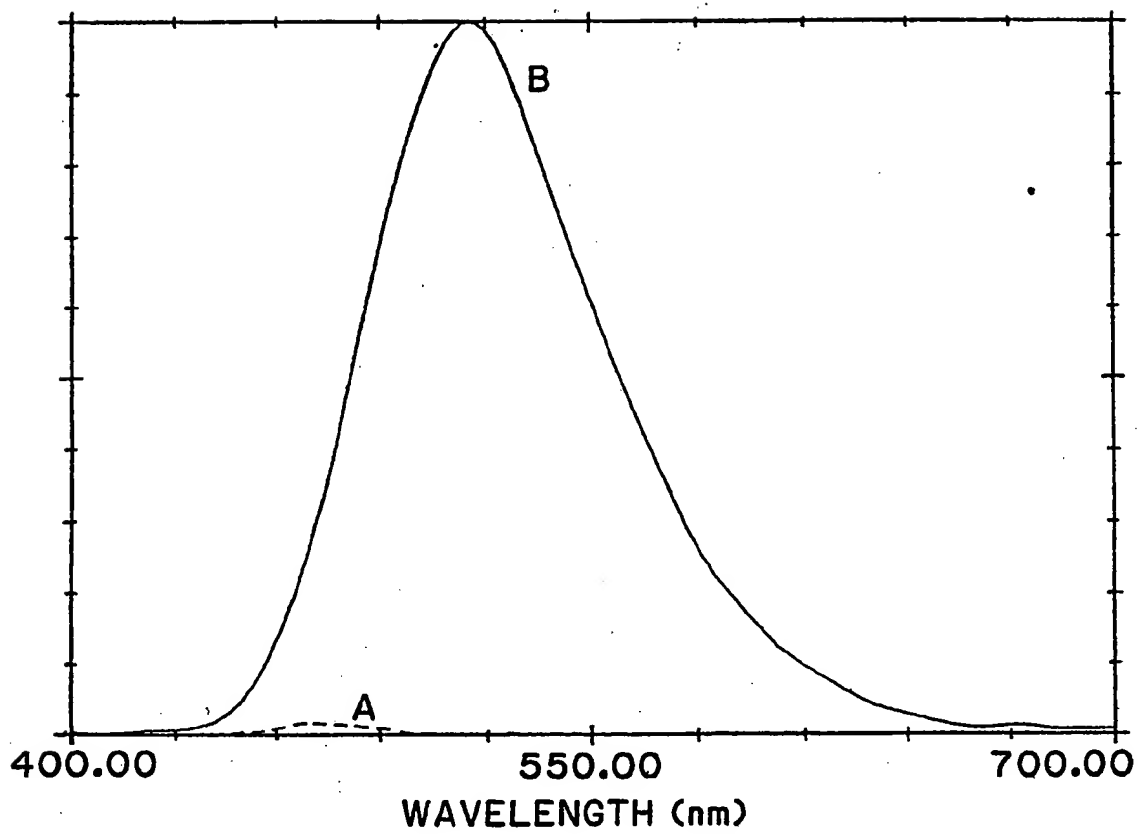


FIG. 3

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**FIG. 4****SUBSTITUTE SHEET**

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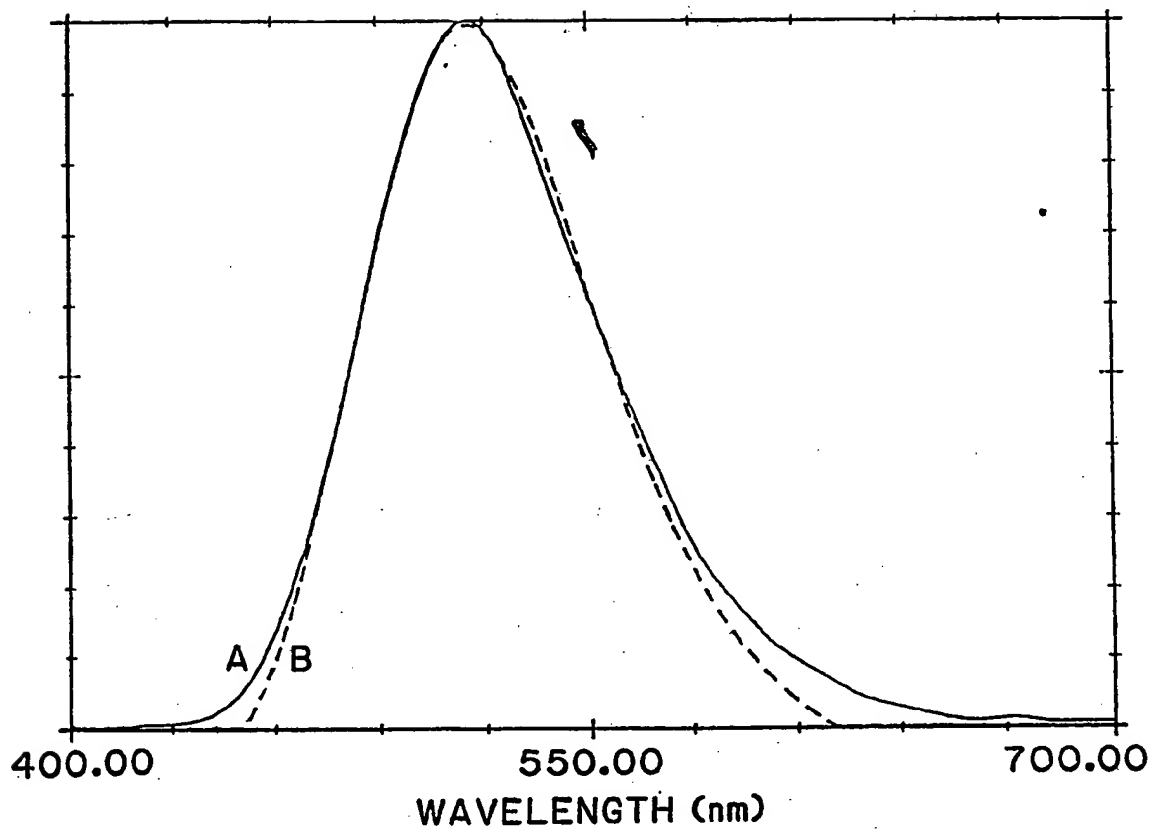


FIG. 5

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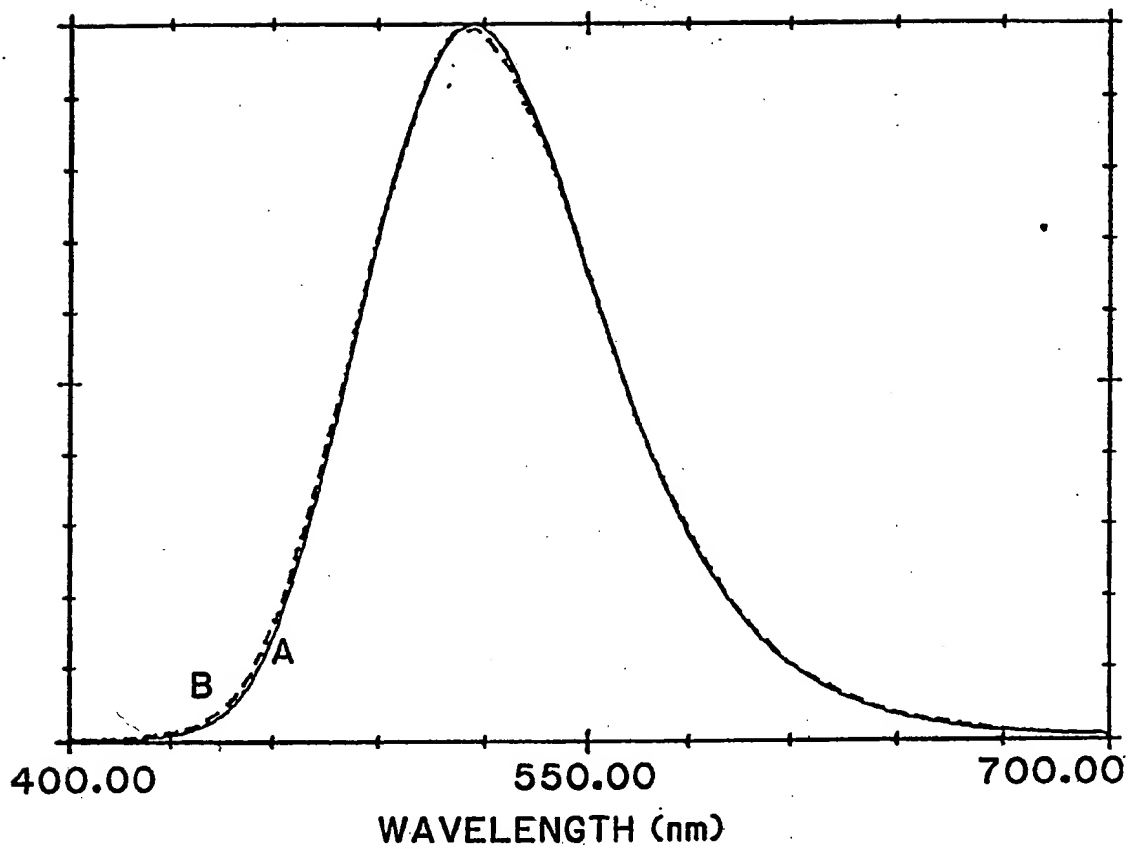


FIG. 6

SUBSTITUTE SHEET

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/05741

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) \*

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5) C07F 9/09; C07D 277/62

U.S. Cl: 548/113; 548/147

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>7</sup>

Classification System	Classification Symbols
U.S.	548/113; 548/147

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>

Category <sup>*</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	US, A, 3,720,622 (BOLLYKY) 13 March 1973, See entire document	9-13,33,34, 36,38
A	Adam, W., Chemische Berichte., 116, p. 839 (1983)	9-13,33,34,36 38

\* Special categories of cited documents: <sup>10</sup>

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"d" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

30 March 1990

International Searching Authority

ISA/US

Date of Mailing of this International Search Report

26 APR 1990

Signature of Authorized Officer

*Catherine S. Kilby Scalzo*  
Catherine S. Kilby Scalzo